AD 688173

ENGINEERING STUDY OF
BLAST-RESISTANT DOORS
Submitted to
U. S. CORPS OF ENGINEERS
Protective Construction Branch
Contract No. DA-49-129-ENG-434

by

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Mosler Safe Co.
30 November 1960

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NOMENCLATURE

DLF	Dynamic Load Factor (to convert a given dynamic load to an equivalent static load)
E	Modulus of elasticity (psi)
f_{dy}	Dynamic yield strength of steel (psi)
I	Moment of inertia (inches^4)
K_L	Load factor
K_M	Mass factor
K_{LM}	Load mass factor
k	Spring factor (kips/foot)
M	Bending moment (inch-pounds)
P_r	Reflected shock wave overpressure (psig)
P_{so}	Overpressure (psig)
S	Section modulus (inches^3)
T	Time of idealized triangular load (seconds)
T_n	Natural period of oscillation (seconds)
t	Time in seconds
t_+	Positive phase duration (seconds)
U_o	Shock front velocity (feet per second)

SYNOPSIS

This final report is the nuclear-blast-resistant door section of a study, which also includes blast valve closures, under Contract DA-49-129-ENG-434 with the Protective Construction Branch, U. S. Corps of Engineers, Washington, D. C. Blast valve closures were covered in a separate report. (1)

The purpose of this report is to evaluate various existing blast-resistant door designs and then to select the optimum door designs for the door sizes, types, and blast pressure ratings specified in the contract, taking into consideration economy, ease of manufacture from standard available materials, reliability of operation, and a minimum amount of maintenance.

From the optimum door designs complete drawings and specifications were prepared suitable for competitive bidding and manufacture.

This report summarizes the results of the Interim Blast Door Study (2) which included detailed preliminary design calculations, sketches, and comparisons.

SECTION I - SCOPE OF WORK

The criteria specifies 25, 50, and 100 psi overpressures (see Figures I-1, I-2, and I-3, which are compiled from item 3 in the Bibliography), with full reflected pressures to be withstood elasto-plastically by the doors, which are to be operable after three blasts under conditions of moisture and extremes of temperature with a minimum of maintenance.

The door sizes and types to be considered are as follows (see Figure I-4):

A. Pedestrian door 3'-6" wide x 7'-0" high, single-leaf, side-hinged

B. Pedestrian door 6'-0" wide x 7'-0" high, double-leaf, side-hinged

C. Vehicular door 8'-0" x 8'-0", double-leaf, side-hinged

D. Vehicular door 12'-0" x 12'-0", single- and double-leaf, sliding

E. Rail and truck door 14'-0" wide x 18'-0" high, single-leaf, sliding

F. Hatch door 3'-0" x 3'-0", single-leaf, side-hinged, suitable for horizontal or vertical mounting

G. Service tunnel door 2'-6" wide x 4'-0" high, single-leaf, hinged

Door sizes mentioned above are clear opening sizes. The 12'-0" x 12'-0", 25 psi rating, double-leaf, sliding door is powered by a manually operated hand chain geared trolley. The 12'-0" x 12'-0", 50 and 100 psi rating, single-leaf sliding doors, and the 14'-0" x 18'-0", 25, 50, and 100 psi rating, single-leaf sliding doors are powered by electric motor drives with an emergency manual handwheel drive.

The remainder of the doors are manually opened and shut, either single or double-leaf. By using bank-vault-door type three-way adjustable hinges, the door leaves are easily opened and shut by one person with just a few pounds pull on the door handle, even though the door leaf may weigh 5 tons or more.

The doors were designed complete with frame and hardware. Doors and frames (except for sliding doors) were designed as integral units. The frames are of a one-piece box construction. The doors are designed to be mounted in the door frames, adjusted and operated at the factory, and shipped together as one unit, thus insuring proper fit and operation on the job.

Doors are also designed to resist a 25% maximum rebound force, except where calculations indicate a greater percentage, in which case the calculated figure is used. The rebound force is taken care of by a bank-vault-door type locking bolt mechanism.

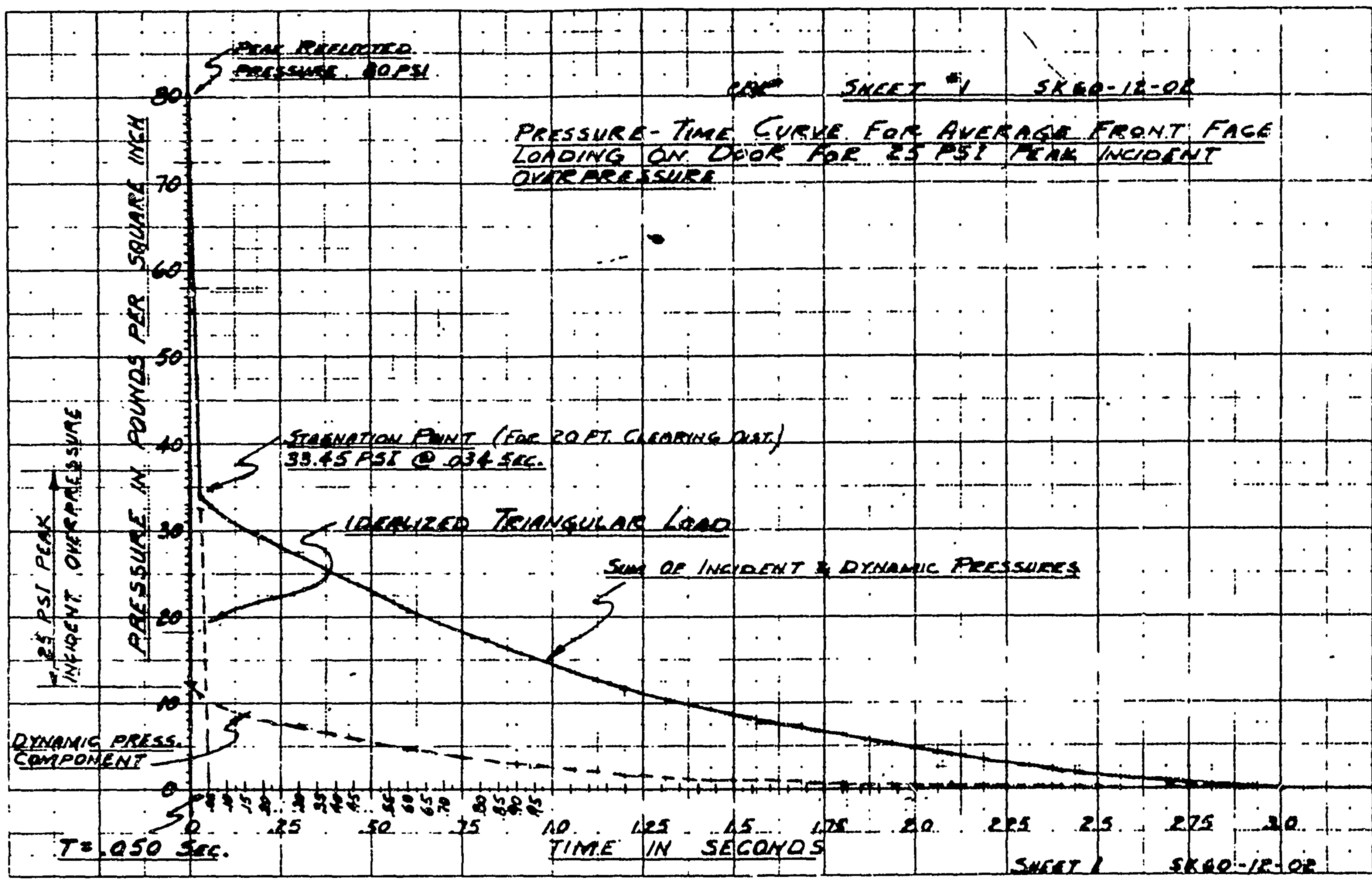

PEAK REFLECTED PRESSURE 80 PSI
SHEET #1 SK60-12-02
PRESSURE-TIME CURVE FOR AVERAGE FRONT FACE LOADING ON DOOR FOR 25 PSI PEAK INCIDENT OVERPRESSURE
PRESSURE IN POUNDS PER SQUARE INCH
STAGNATION POINT (FOR 20 FT. CLEARING DIST.) 33.45 PSI @ .034 SEC.
IDEALIZED TRIANGULAR LOAD
SUM OF INCIDENT & DYNAMIC PRESSURES
25 PSI PEAK INCIDENT OVERPRESSURE
DYNAMIC PRESS. COMPONENT
80
70
60
50
40
30
20
10
0
0
.25
.50
.75
1.0
1.25
1.5
1.75
2.0
2.25
2.5
2.75
3.0
T = .050 SEC.
TIME IN SECONDS
SHEET 1 SK60-12-02

Figure I-1

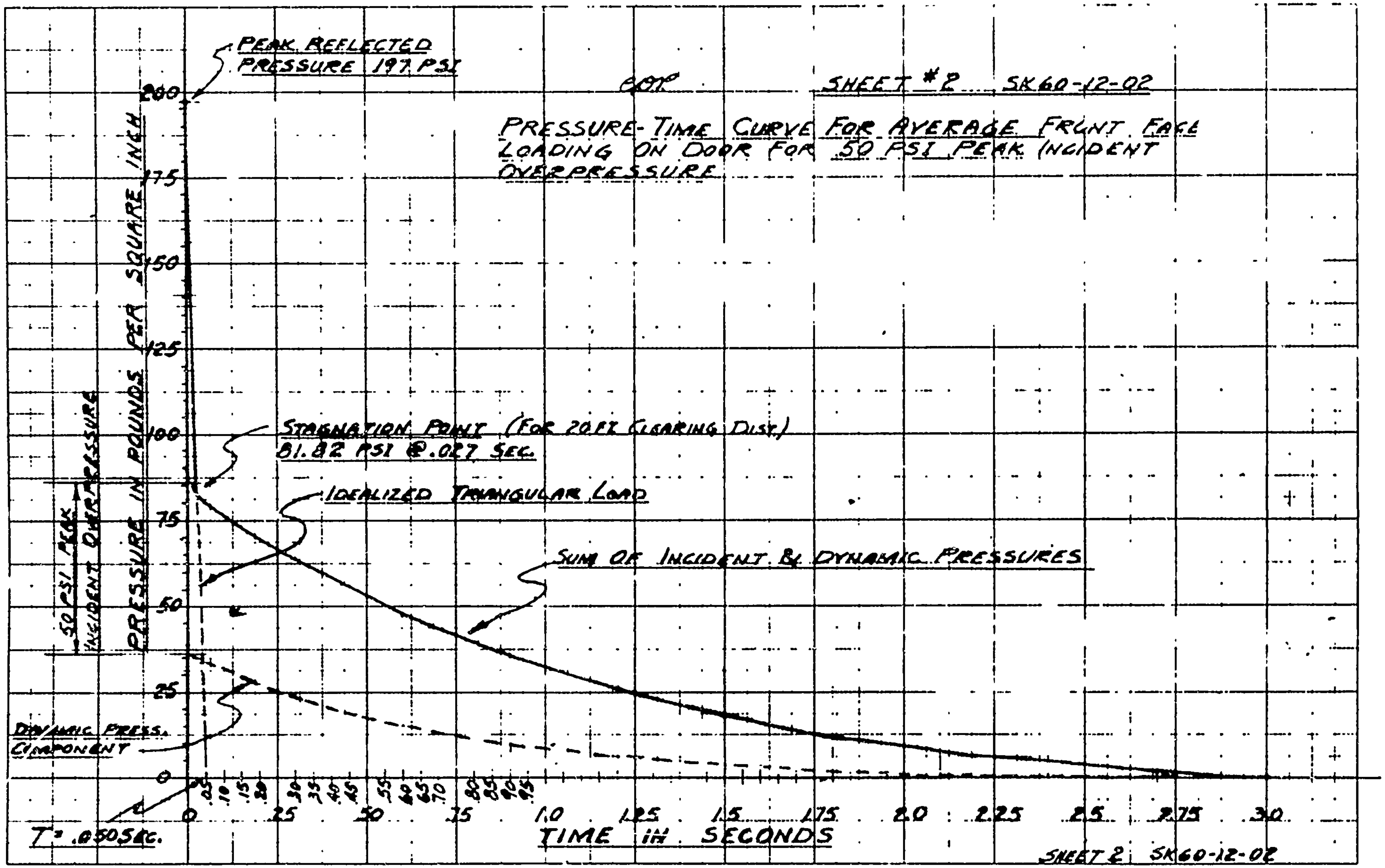

PEAK REFLECTED PRESSURE 197 PSI
SHEET #2 SK60-12-02
PRESSURE-TIME CURVE FOR AVERAGE FRONT FACE LOADING ON DOOR FOR 50 PSI PEAK INCIDENT OVERPRESSURE
STAGNATION POINT (FOR 20 FT CLEARING DIST.)
81.82 PSI @ .027 SEC.
IDEALIZED TRIANGULAR LOAD
SUM OF INCIDENT & DYNAMIC PRESSURES
50 PSI PEAK INCIDENT OVERPRESSURE
PRESSURE IN POUNDS PER SQUARE INCH
DYNAMIC PRESS. COMPONENT
T = .050 SEC.
TIME IN SECONDS
SHEET 2 SK60-12-02

Figure I-2

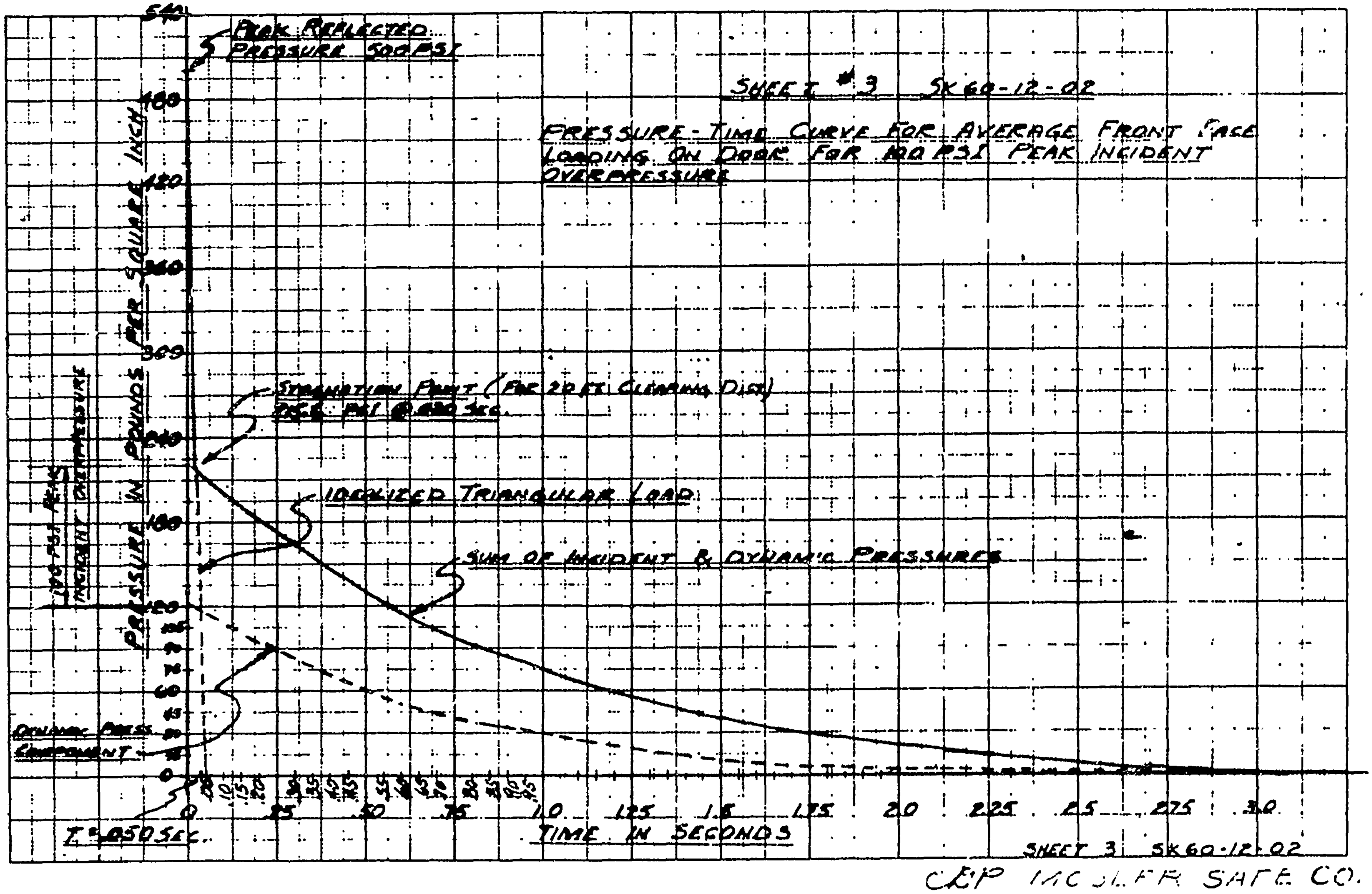
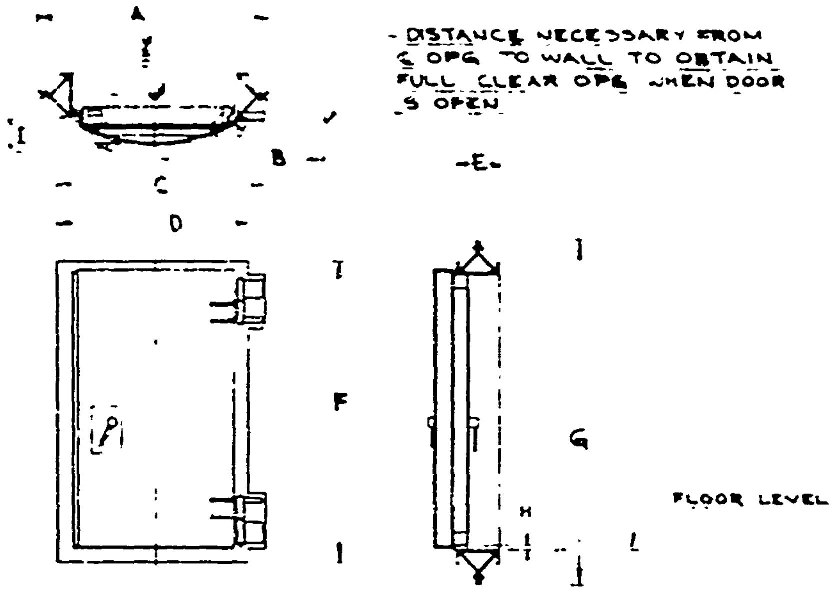
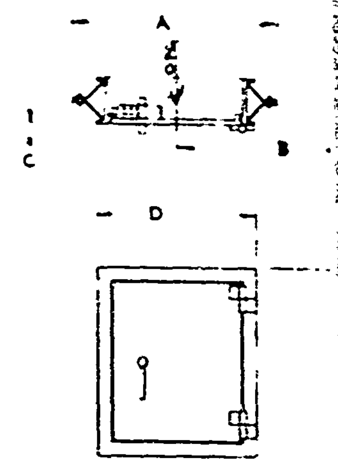

PEAK REFLECTED PRESSURE 500 PSI
SHEET #3 SK60-12-02
PRESSURE-TIME CURVE FOR AVERAGE FRONT FACE LOADING ON DOOR FOR 100 PSI PEAK INCIDENT OVERPRESSURE
PRESSURE IN POUNDS PER SQUARE INCH
STAGNATION POINT (FOR 20 FT CLEARING DIST)
IDEALIZED TRIANGULAR LOAD
SUM OF INCIDENT & DYNAMIC PRESSURES
100 PSI PEAK INCIDENT OVERPRESSURE
DYNAMIC PRESS COMPONENT
TIME IN SECONDS
SHEET 3 SK60-12-02
CEP MOSLER SAFE CO.

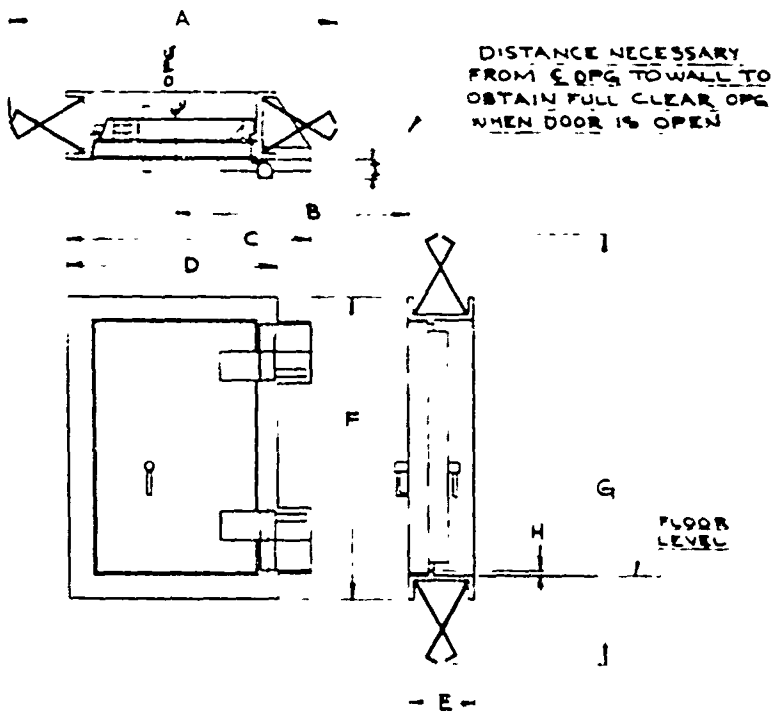
Figure I-3



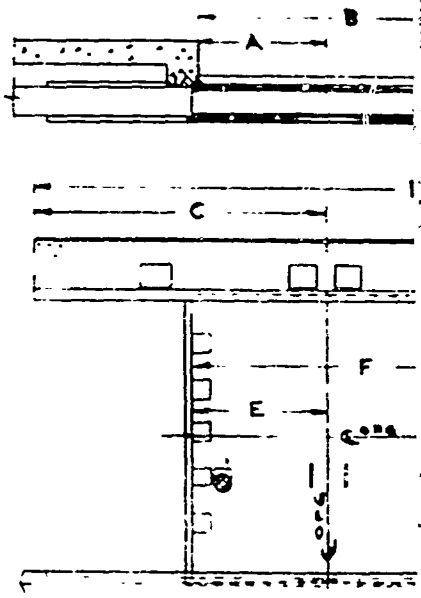
SIZE	PRESSURE	A	B	C	D	E	F	G	H	I	SHIPPING WT.
3'-6"x7'-0"	25 PSI	64	58½	57 1/16	52	12	91½	102½	5/8	9 13/16	3500



SIZE	PRESSURE	A
3'-0"×3'-0"	25 PSI	61[illegible]
3'-0"×3'-0"	50 PSI	67
3'-0"×3'-0"	100 PSI	84
2-6"×4'-0	25 PSI	56
2-6"×4'-0"	50 PSI	60[illegible]
2-6"×4'-0"	100 PSI	68[illegible]

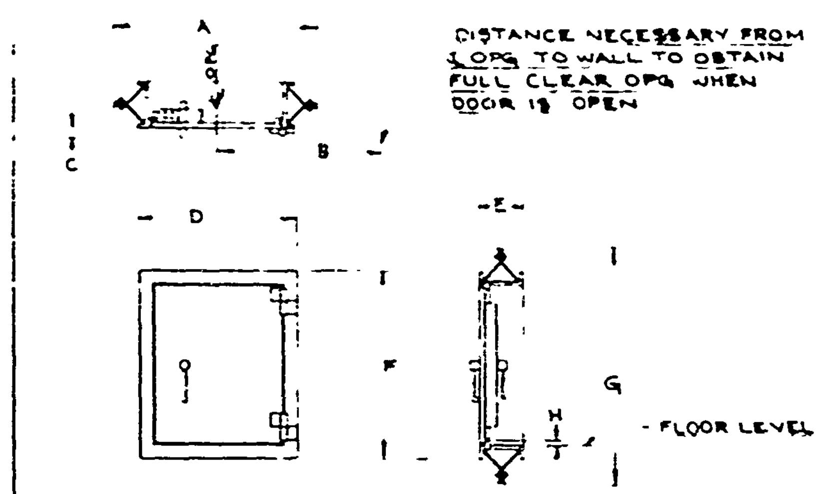


SIZE	PRESSURE	A	B	C	D	E	F	G	H	I	SHIPPING WT
3'-6"×7'-0"	50 PSI	71 3/8	44	63 3/8	55 3/8	18	95¼	111¼	5/8	4¾	6000
3'-6"×7'-0"	100 PSI	83½	68	64 3/8	58 1/8	24	98¼	124¼	7/8	4¾	10400

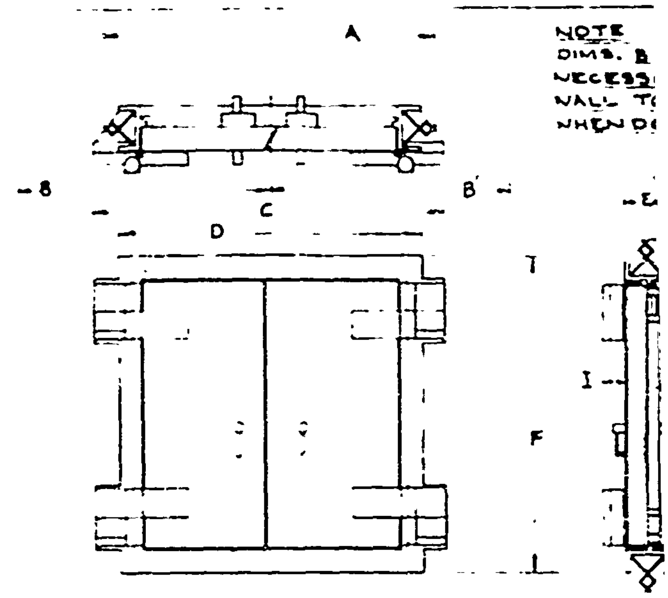


SIZE	PRESSURE	A
12-0"x12'-0"	25 PSI.	6-0

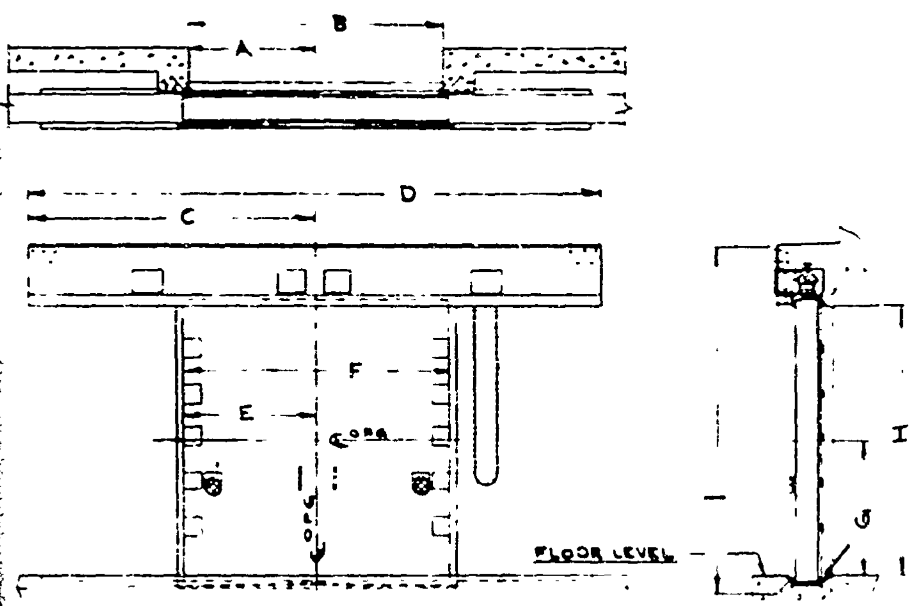
A



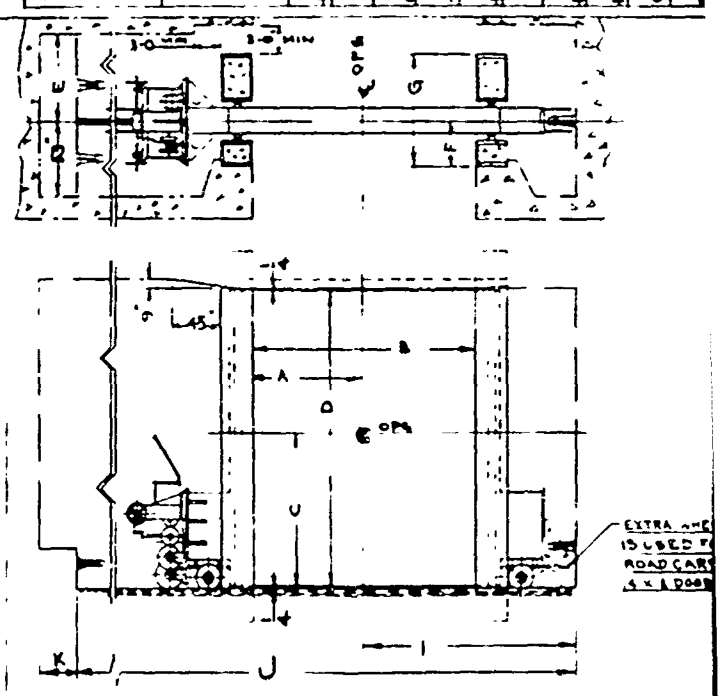
SIZE	PRESSURE	A	B	C	D	E	F	G	H	SHIPPING WT.
3'-0" × 3'-0"	25 PSI	61 3/8	55 3/4	3 1/4	45 3/8	12	44 3/4	60 3/4	5/8	850
3'-0" × 3'-0"	50 PSI	67	55 3/4	3 1/2	45 3/4	18	44 1/4	66	5/8	3000
3'-0" × 3'-0"	100 PSI	84	55 1/4	3 1/4	46 3/8	24	45 1/4	72 1/4	5/8	3200
2-6" × 4'-0	25 PSI	56	46 1/4	2 1/2	41 1/8	12	37 1/4	72 1/2	5/8	1400
2-6" × 4'-0"	50 PSI	60 3/8	47	3	40 7/8	18	57 1/2	77 1/4	5/8	3000
2-6" × 4'-0"	100 PSI.	68 3/8	47	3 1/4	40 5/8	24	57 1/4	85 1/4	5/8	4400



SIZE	PRESSURE	A	B	B'	C	D	E	F	G	H	I
6-0" × 7-0"	25 PSI	91 1/2	36 1/2	38	99 1/4	85 1/4	12	97 1/4	104 3/4	5/8	4 3/4
6-0 × 7-0"	50 PSI	102 3/4	40	40	99 1/4	83 1/4	18	97 1/4	96 3/4	5/8	4 3/4
6-0" × 7-0	100 PSI	105 3/4	40	41	104 1/2	86 1/2	24	98 1/2	120 3/4	1 1/4	5 [illegible]
8-0" × 8-0	25 PSI	10 3/4	47	49 1/2	123 1/4	109 3/4	12	109 3/4	117 3/4	8	4 3/4
8-0" × 8-0	50 PSI	29 1/2	50	56 1/2	134 1/4	110 1/4	18	118 1/4	126 3/4	1 1/8	6 1/2
8-0" × 8-0"	.00 PSI	137 1/4	50	54 1/2	134 1/4	112 1/4	24	10 3/4	137 3/4	1 3/8	6 [illegible]



SIZE	PRESSURE	A	B	C	D	E	F	G	H	I	SHIPPING WT
12-0" × 12-0"	25 PSI	6-0	12-0	13 6	27-0	6-3	12-6	6-0	12-0	15-4 1/2	35 500



SIZE	PRESSURE	A	B	C	D	E	F	G	H	I	J
12-0" × 12-0"	50 PS.I	6-0"	12-0"	6-0"	12-0	5-7"	3-11 1/2	9-3 1/2	17-0	12-6	44-10
2'-0" × 12'-0	100 PSI	6-0	12-0	6-0"	12-0	5-7"	4-6 1/2	11-7 1/2	17-0	12-6"	44-10
14-0" × 18-0	25 PSI	7-0"	14-0"	9-0	18-0	5-7	2-7 1/2	4-1 1/2	22-0	14-4"	50-4"
4'-0" × 18'-0"	50 PS.I	7-0	14-0	9-0"	18-0	6-2	4-0"	6-6	22-0	14-6	51-7"
14'-0" × 18'-0"	100 PSI	7-0	14-0	9-0"	18-0"	5-7"	3-6	5-10 1/2	24-0"	14-1	54-4

GENERAL NOTES

PRESSURE SHOWN ARE INCIDENT BLAST OVER PRESSURE
- DOORS DESIGNED TO RESIST FULL REFLECTED PRESSURES

REVISION

Drawn by C. Oden Date 6 16 60

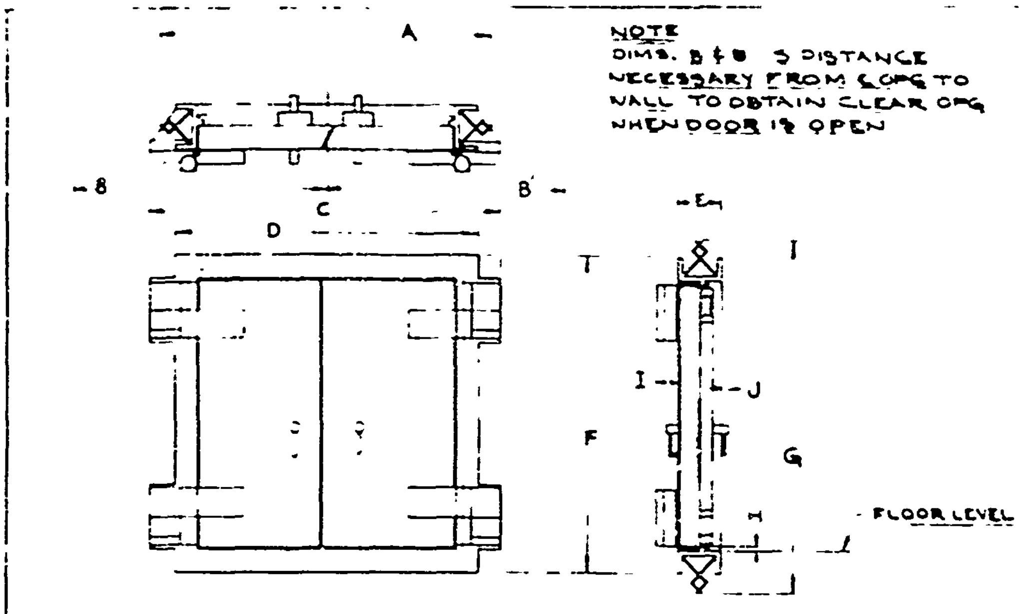
TITLE BLA

11

...SS .RY FROM
TO OBTAIN
PG WHEN

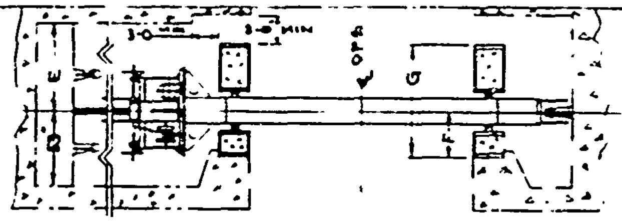
FLOOR LEVEL

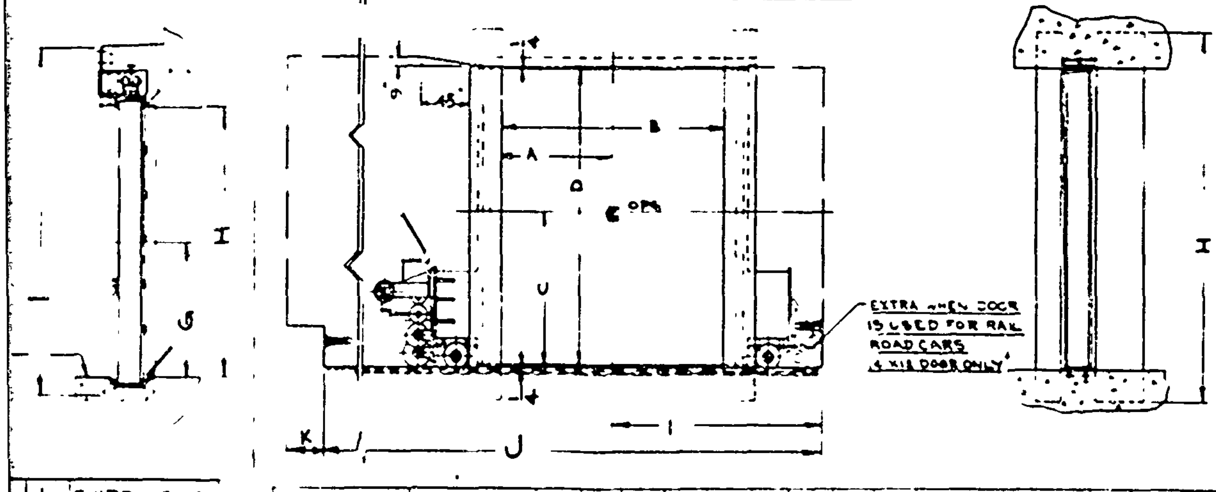
H	SHIPPING WT.
/8	850
/8	3000
/8	3200
/8	1400
/8	3000
/8	4400



SIZE	PRESSURE	A	B	B'	C	D	E	F	G	H	I	J	SHIPPING WT
6-0"×7-0"	25 PSI.	91½	36½	38	99¼	85¼	12	97¼	104¾	⅝	4¾	3 5/32	8000
6-0 ×7-0"	50 PSI	102¾	40	40	99¼	83¼	18	97¼	96¾	⅝	4¾	—	13,100
6-0"×7-0	100 PSI	105¾	40	41	104½	86½	24	98½	120¾	1¼	5¼	—	19 600
8-0"×8-0	25 P.SI	116¾	47	49½	123¼	109¾	12	109¼	117¾	⅞	4¾	3½	13 900
8-0"×8-0	50 PSI	129¼	50	56½	134¼	110¼	18	110¼	126¾	1⅛	6½	—	19000
8-0"×8'-0"	100 PSI	137¼	50	54½	134¼	112¾	24	110¼	137¾	1⅜	6½	—	42 250

Figure I-4





I	SHIPPING WT
15-4½	35 500

SIZE	PRESSURE	A	B	C	D	E	F	G	H	I	J	K			SHIPPING WT
12-0" X 12-0"	50 PSI	6-0"	12-0"	6-0"	12-0	5-7"	3-11	9-5	17-0	12-6	44-10	2-4			124,500
12-0" X 12-0	100 PSI	6-0	12-0	6-0"	12-0	5-7"	4-6	11-7	17-0	12-6"	44-10	2-4			152,500
14-0" X 18-0	25 PSI	7-0"	14-0"	9-0	18-0	5-7"	2-7½	4-	22-0	14-4"	50-4"	2-4			115,000
14-0" X 18'-0"	50 PSI	7-0"	14-0	9-0"	18-0	6-2	4-0	6-6	22-0	13-6	51-7	2-4			180,108
14'-0" X 18'-0"	100 PS I	7-0	14-0	9-0"	18-0	5-7"	3-8	5-10½	24-0	14-1	54-4	2-4			284,000

GENERAL NOTES
...URE SHOWN ARE
...NT BLAST OVER PRESSURE
...S DESIGNED TO RESIST
...EFLECTED PRESSURES

RUGNE VAS 6-6-60

REVISIONS

TOLERANCE UNLESS SPECIFIED
DECIMAL
FRACTIONAL
ANGULAR
Drawn by C. Oden
Date 6-16-60
Checked by
Scale
Material
Finish
Book Rev

MOSLER HAMILTON OHIO

TITLE STD OCE TYPE BLAST RESISTANT DOORS

D-450318

11

SECTION II - REVIEW OF EXISTING ELAST DOORS STUDIED

Rather than a detailed list of all door drawings available for study (which would be unduly voluminous), a representative cross-section of various doors is presented.

Drawing	Description
Ammann & Whitney 60-02-058, Sheet #18 5'-4" x 7'-2" opening Side-hinged	Constructed of 8" channel and beams running short way of door with 3/8" outer plate and 1/4" back plate. 3 side hinges, 3 separate manual latches, and rubber gasket.
Ammann & Whitney 60-02-58, Sheet #17 10'-0" x 14'-0" sliding door	Constructed of 14" @ 43 WF beams running long way of door with 3/8" outer plate and 1/4" back plate. Runs on three 2-ton trolleys. Sealing gasket and turnbuckle anchor dogs.
Ammann & Whitney Sheet #1 & Sheet #2 6'-0" x 8'-0"	Constructed of 8" thick solid steel plate. Moved on double flanged wheels on bottom of door. Sliding door.
Black & Veatch 33-15-58, Sheet #9 12'-0" x 12'-0" Double sliding door	Constructed of 12" "I" beams running long way. 9/16" thick steel plates front and back. Runs on trolleys. 3/16" x 1-1/2" rubber-impregnated canvas belting for seals.
Black & Veatch 33-03-15, Sheet #8 3'-0" x 6'-8"	Constructed of 4" channels running short way of door with 3/8" thick steel plates front and back. Spring bronze seals. Side hinged door.
Black & Veatch 33-03-15, Sheet #7 8'-0" x 8'-0"	Constructed of 6" "I" beams running long way with 5/8" thick steel plates front and back. Spring bronze seals. Double-leaf, side-hinged door.

Drawing	Description
Lorenzo S. Winslow 49-100-9 3'-0" x 6'-6" Side-hinged	Constructed of structural tees, ST 5 I's running short way and ST 5 B's running long way, with 7/16" thick steel outer plate and 1/4" thick steel back plate.
Lorenzo S. Winslow 49-100-9 4'-8" x 6'-6" Side-hinged	Double door, constructed of structural tees, ST 5 I's running long way and 5" x 1-1/8" bars running short way, with 1/2" thick steel outer plate and 1/4" thick steel back plate.
Leo A. Daly A-11 7'-9" high Single- and Double-leaf, side-hinged	Constructed of 1/4" thick steel plate with 3" x 2" x 1/4" angle frame, with canvas-covered rubber gasket and refrigerator type handle and latch.
General Services Administration 49-100-9 3'-8-1/2" x 6'-7-1/8" Side-hinged	6-11/16" thick door consists of structural tees, ST 6 I's running short way and ST 6 B's running long way, with 6" channel outer frame, with 7/16" thick steel outer plate and 1/4" thick steel back plate.
General Services Administration 49-100-9 2'-8" x 6'-7" Side-hinged	5-11/16" thick door consists of structural tees, ST 5 I's running short way and ST 5 B's running long way, with 5" channel outer frame, with 7/16" thick steel outer plate and 1/4" thick steel back plate.
Faulkner, Kingsbury, & Stenhouse	13 various size doors consisting of 5/8" or 7/8" thick solid steel plate on outer or hinge side and an outside frame of 3-1/2" x 1" steel bar with a 1/8" steel back cover plate.
Daniel, Mann, Johnson & Mendenhall & Associates AP-1511/16 5'-0" x 7'-0"	2" thick curved steel plate, side-hinged door.

From the preceding summary of existing door designs, the following generalities are obtained:

1. Large doors are of built-up construction with a heavy front and back steel plate, with structural steel beams between the plates.

2. Built-up-construction doors feature more one-way construction than two-way construction. On double-leaf doors the one-way construction runs the long way of the door due to the one edge of the door being unsupported.

3. Built-up-construction doors with two-way reinforcement feature a "tee" beam reinforcement which allows the leg of the tee to be welded to one plate and the other plate to be slotted and welded to the flange of the tee from the outside, overcoming what would otherwise be a fabrication problem. Two-way reinforcement is very much in the minority, however.

4. Small or medium strength and size doors might be made of a solid steel plate as well as of a built-up fabrication.

5. There is a wide variety of hinges and latching devices, practically none of which appear adequate and capable of withstanding significant rebound forces.

6. Little progress has been made in the design of doors departing from conventional designs, such as curved doors or prestressed concrete doors.

Of considerable interest, in addition to the above-mentioned doors, is a particular door design which was successfully tested in 1957 in "Operation Plumbbob" at the Nevada Test Site under very high pressures. This was a standard bank vault door, a Mosler Safe Co. C-10 door. The damage to the door was only superficial, peeling off ornamental trim, etc., the door being reopened without any difficulty. The interior of the above-ground vault was entirely protected by the door. Although the concrete covering of the vault was badly damaged, the steel lining of the vault kept it air tight. This door is shown in Figures II-1, II-2, II-3, II-4, and II-5.

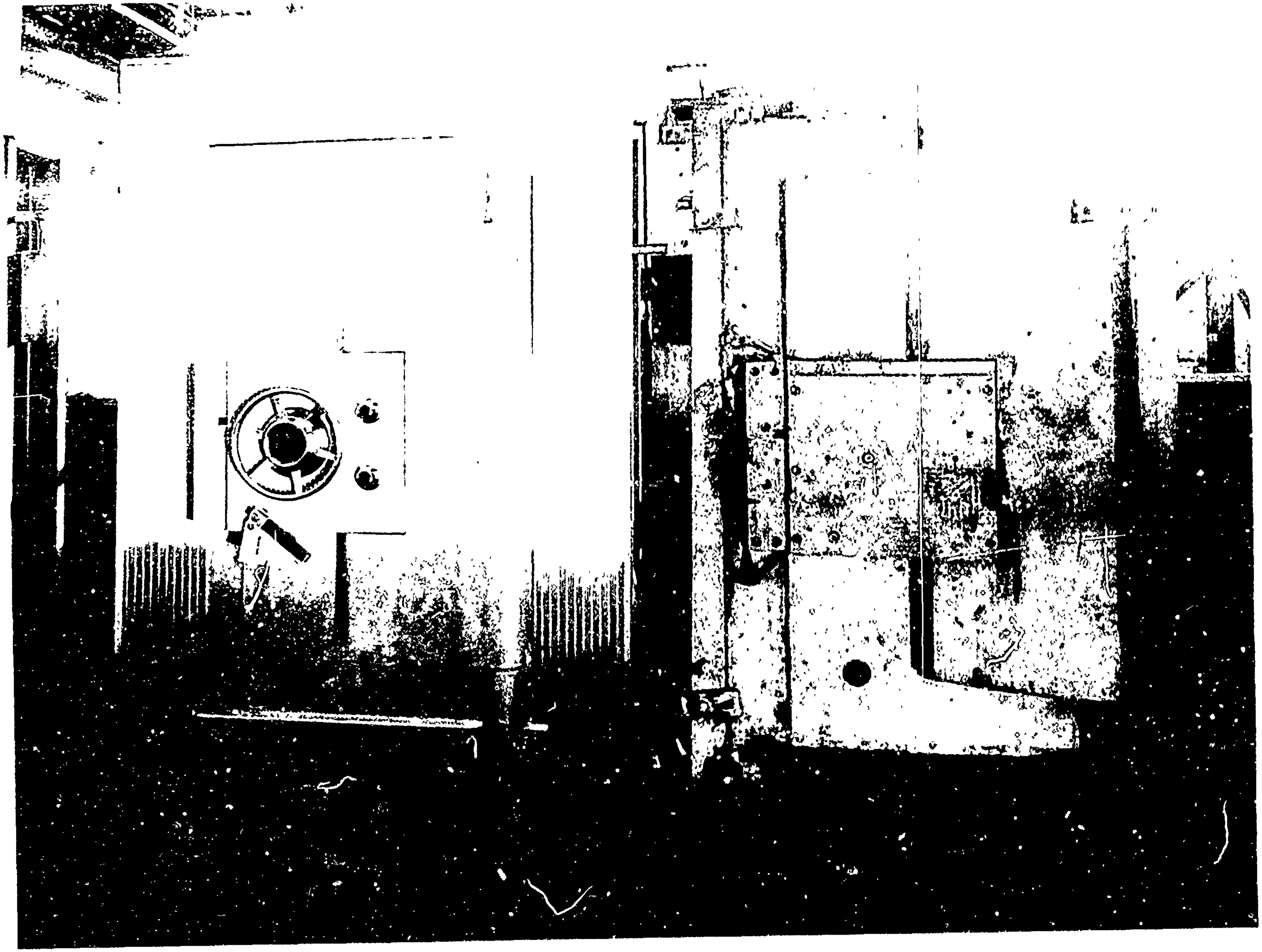


Figure II-1

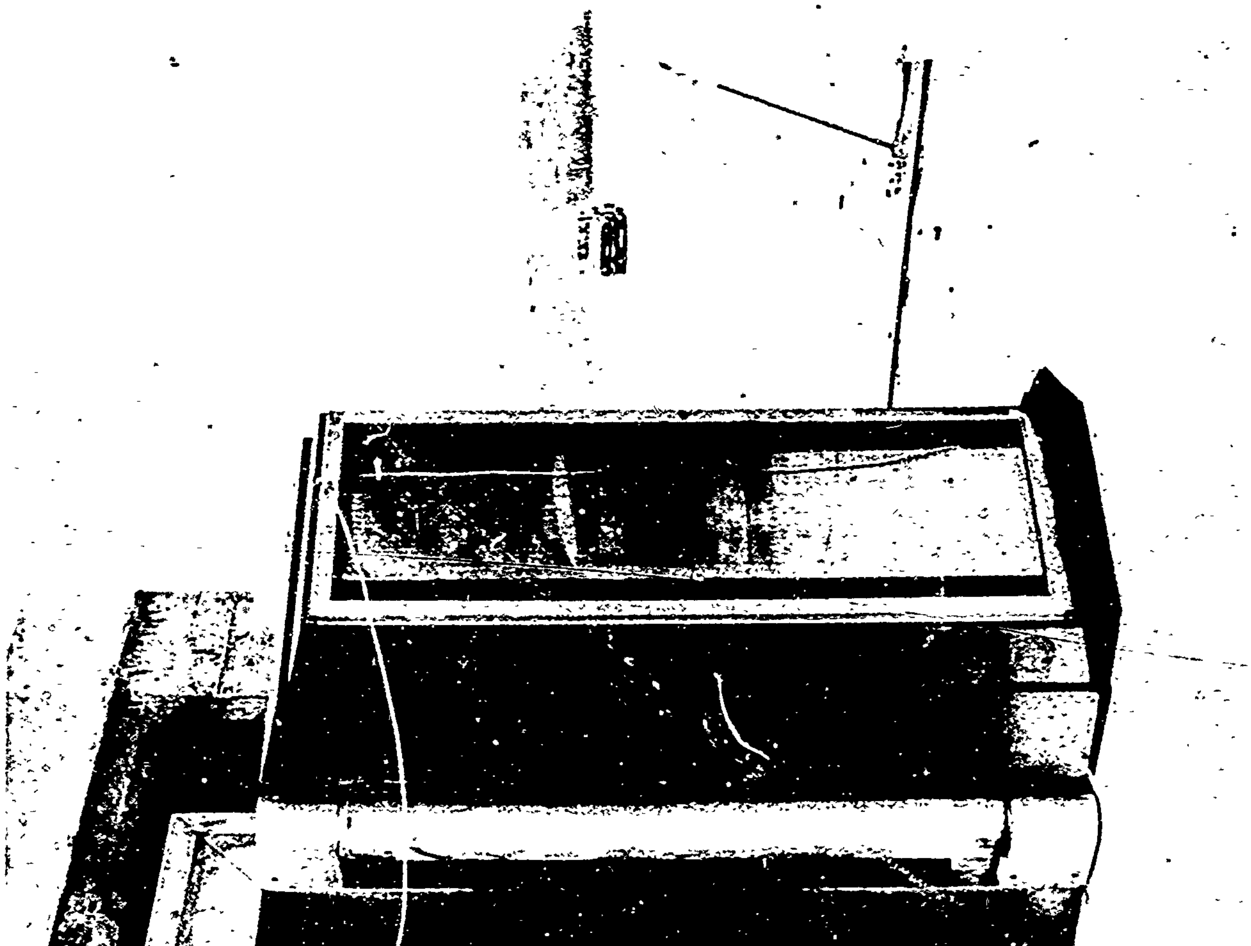


Figure II-2

Figure II-3

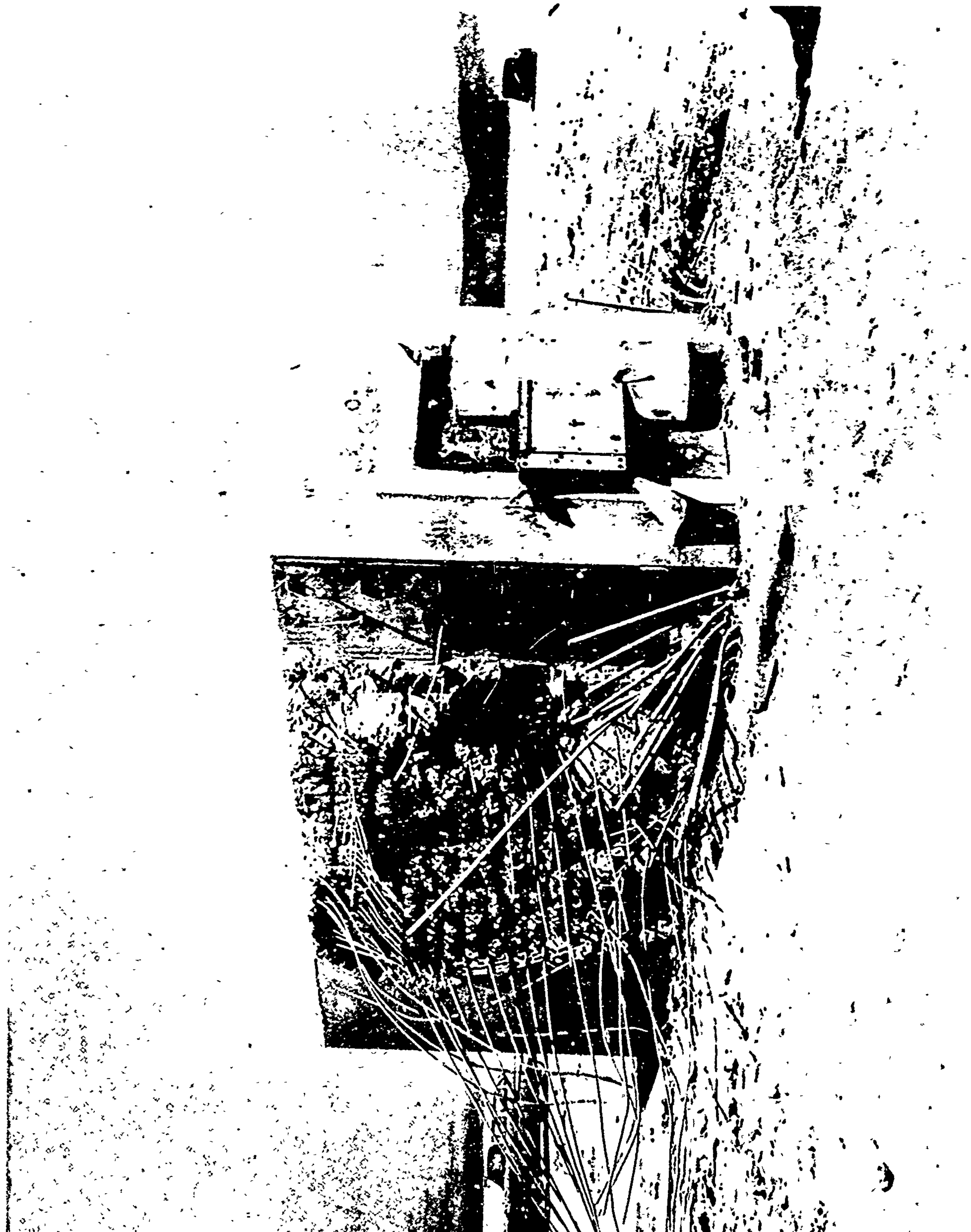


Figure II-4

NOT REPRODUCIBLE

Figure II-5

SECTION III - COMPARISON OF DOOR DESIGNS AND FINAL DOOR DESIGN SELECTIONS

There are several possibilities of door designs and materials. Possible designs included:

A. Solid flat plate door leaves

B. One-way reinforced built-up welded door leaves

C. Two-way reinforced built-up welded door leaves

D. Curved door leaves

Possible materials for door leaves included:

A. Aluminum

B. Concrete

C. Plastic

D. Steel

Referring to Interim Blast-Resistant Door Study (2), for reasons of economy and ease of fabrication, steel was selected as the best material.

Likewise, for the various possible door designs, the one-way reinforced built-up welded door leaf design was selected for all but the lighter section doors. For these doors it was found more economical to use the solid steel flat plate design.

For easy swinging of the hinged type doors, only two hinges should be used for best performance and ease of operation. The bottom hinge contains radial-thrust bearings to take all the downward weight of the door and half of the radial (horizontal) thrust which is due to the rotational effect of the overhang of the door.

The upper hinge takes only the other half of the radial (horizontal) thrust (which is actually a couple). This construction, by relieving the upper hinge bearing of any thrust loads, allows adjustment of the hinge in a vertical direction without danger of overloading the bearings by the adjusting screws. In some designs studied the weight of the door was evenly divided by thrust bearings in the upper and lower hinges, which could result in overloaded hinge bearings if there is a slight misalignment or if one of the vertical adjusting screws is turned too far so that the screw is trying to "jack" against the two bearings and force them apart. In other door designs studied there were three hinges per door leaf, which made this problem even worse. In the final hinged door design the upper hinge bearing "floats" vertically on the hinge pin and is therefore unaffected by vertical adjustment or misalignment.

The top and bottom hinges by being adjustable in the other two directions also, become three-way adjustable. This permits very accurate alignment of the doors so that they swing easily, do not go "up hill" or "down hill", and have no "run" in any position.

Since the door leaf, when closed, seats evenly against a finished section of the door frame all around the door periphery, and is firmly clamped from "rebounding" open by means of the tapered end locking bolt system, the blast forces on the door are isolated from the hinge bearings.

The tapered wedge locking bolt system used in the final design is a duplicate of the same system which has been used for the last 50 years on bank vault doors and was successfully tested under an actual nuclear blast in "Operation Plumbbob."

A completed 6'-0" x 7'-0" double-leaf blast door, 100 psi rating, is shown in Figures III-1 and III-2.

If it is desired to have these blast doors power-operated (say for remote control or interlocking in pairs), this is easily accomplished. Figures III-3 and III-4 show the 3'6" x 7'-0" single-leaf blast door, 100 psi rating, with the additional blast-proof operator.

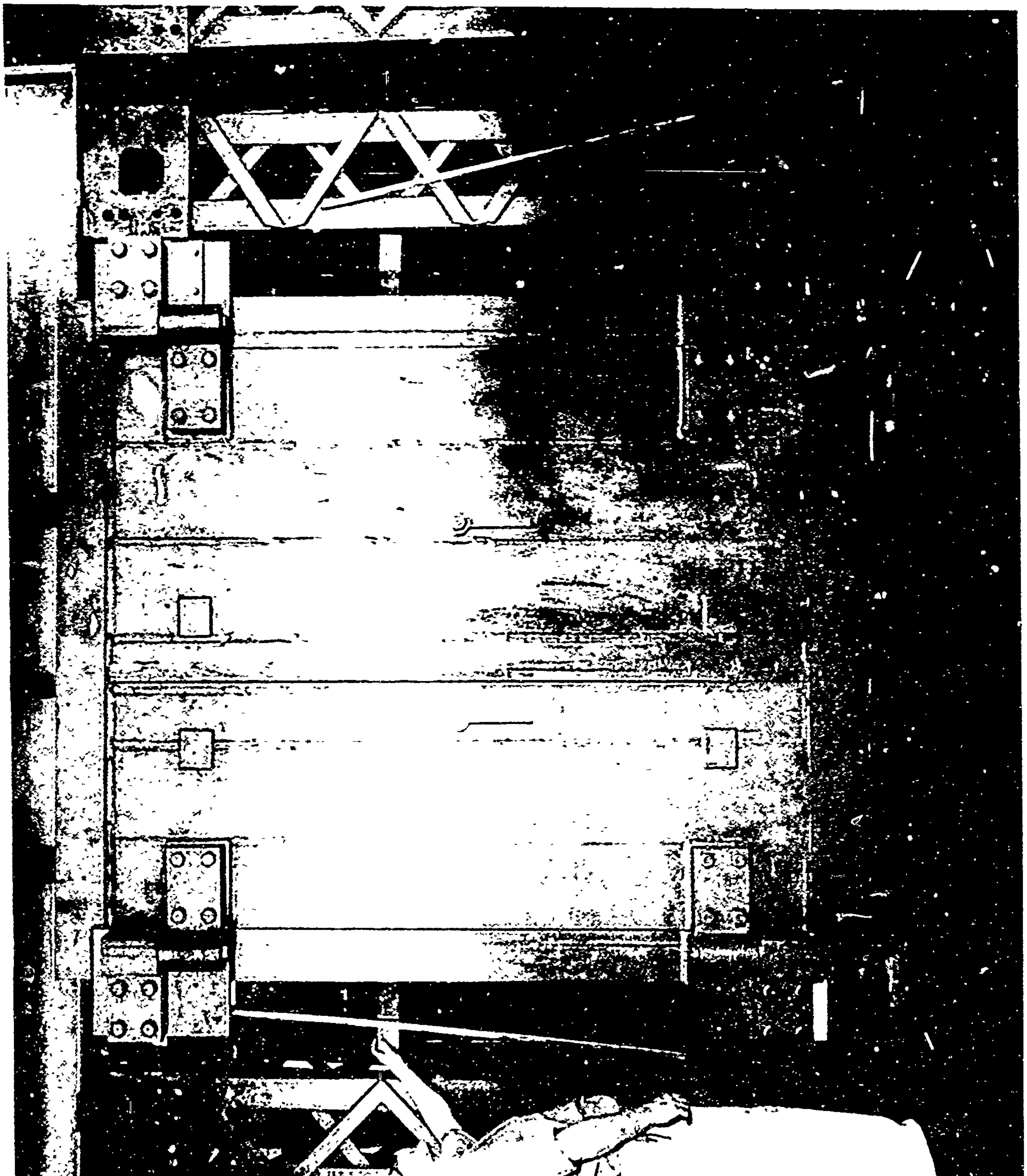


Figure III-1

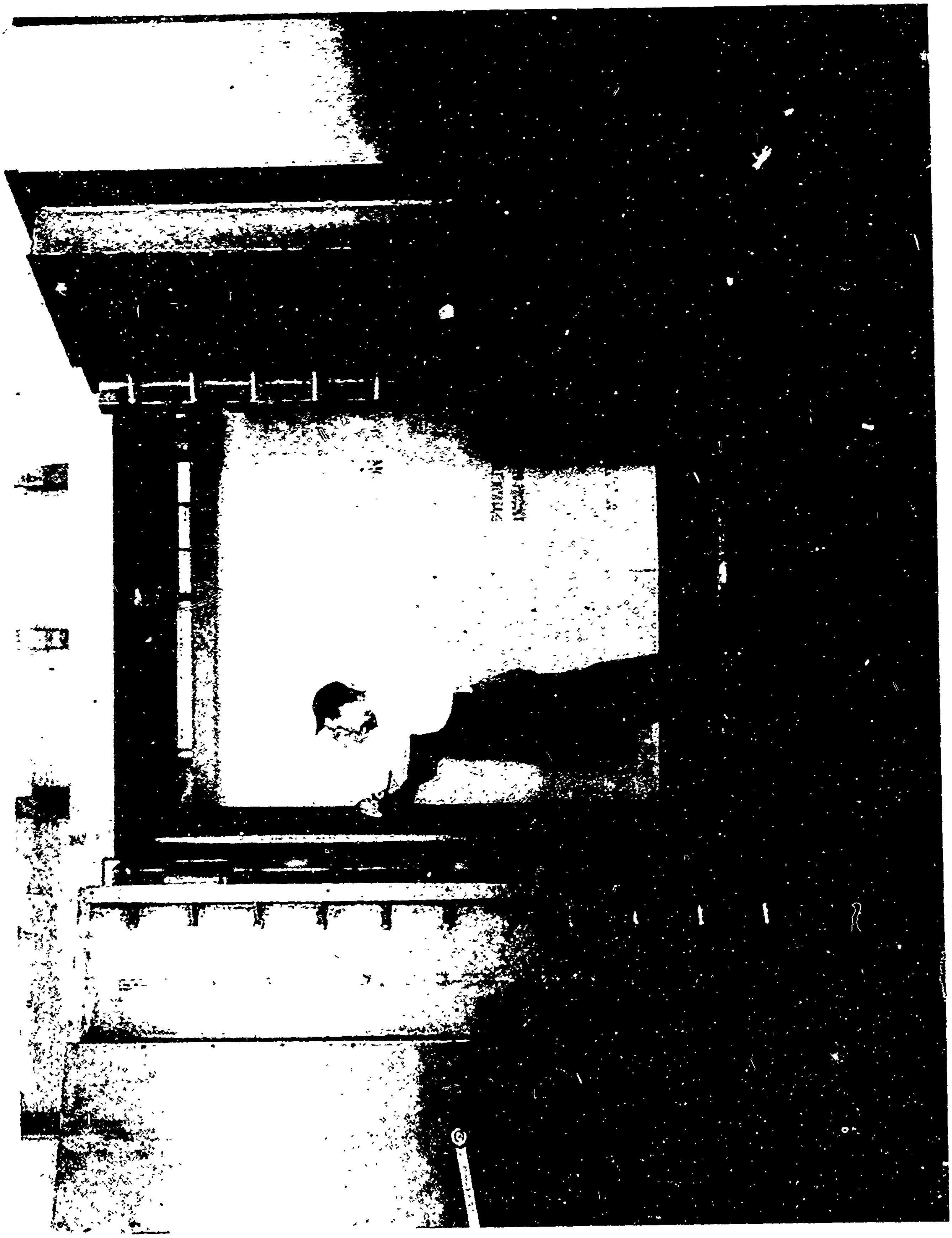


Figure III-2

Figure III-3

NOT REPRODUCIBLE

Figure III-4

A composite list of the door sizes, drawing numbers, and specification numbers of the final door designs is as follows:

Door Size	Drawing Number 25 PSI	50 PSI	100 PSI	Specification Number
3'-6" x 7'-0"	60-12-06	60-12-07	60-12-08	60-12-06-60
6'-0" x 7'-0"	60-12-09	60-12-10	60-12-11	60-12-09-60
8'-0" x 8'-0"	60-12-12	60-12-13	60-12-14	60-12-12-60
12'-0" x 12'-0"	60-12-15	60-12-16	60-12-17	60-12-15-60
14'-0" x 18'-0"	60-12-18	60-12-19	60-12-20	60-12-18-60
3'-0" x 3'-0"	60-12-21	60-12-22	60-12-23	60-12-21-60
2'-6" x 4'-0"	60-12-24	60-12-25	60-12-26	60-12-24-60

SECTION IV - DESIGN CALCULATIONS

In calculating the strengths of the door leafs, there are three basic types of calculations, as follows:

1. Curved door, 3'-6" x 7'-0", 25 psi rating (Figure IV-1)
2. Solid steel plate doors simply supported all four sides, all 3'-0" x 3'-0" and 2'-6" x 4'-0" doors (Figure IV-2)
3. Structural Beam doors welded flange to flange (Figure IV-3)

In the case of the welded structural beam doors, calculations were made on a per beam basis, considering the beam as simply supported each end.

In the case of the solid steel plate doors, the calculations were made on the basis of a plate simply supported on all four sides. Basic plate formulae used were from "Theory of Plates and Shells" by Prof. S. Timoshenko (13).

For the convex curved plate door a completely elastic design was used, as the curved plate would otherwise fail by buckling as soon as the elastic limit was exceeded.

In all cases calculations were made in accordance with the Corps of Engineers Design Manuals (4 through 12). The Design Manuals show two basic approaches, the Energy Method and the Deflection Method. The Deflection Method was chosen as the most suitable. A numerical method of analysis was used in conjunction with an Acceleration Impulse Extrapolation Table.

Recurring constants in the various door calculations were lumped together to form one constant. Derivations of the various constants are shown in Figures IV-5 through IV-

Calculations are broken down into repetitive step-by-step procedures. A certain door section is assumed and then by a series of trials the optimum section is determined.

Typical calculations are shown for the 3'-6" x 7'-0", 25 psi curved door (Figure IV-1), the 3'-6" x 7'-0", 50 psi built-up door (Figure IV-2), the 14'-0" x 18'-0", 50 psi built-up door (Figure IV-3), and the 2'-6" x 4'-0", 100 psi, solid steel plate door (Figure IV-4).

DOOR NO. 60-12-06
TRIAL NO. 1
CURVED DOOR

CALCULATIONS BY T.A.
CHECKED BY H.S.

Door opening = 3'-6" × 7'-0"   Door vertical

Assume 6" bearing width and $\alpha = 60°$, arch fixed at supports

$f_s = 41.6$ ksi

Incident pressure = 25 psi = P_{so}

Peak reflected pressure - 80 psi

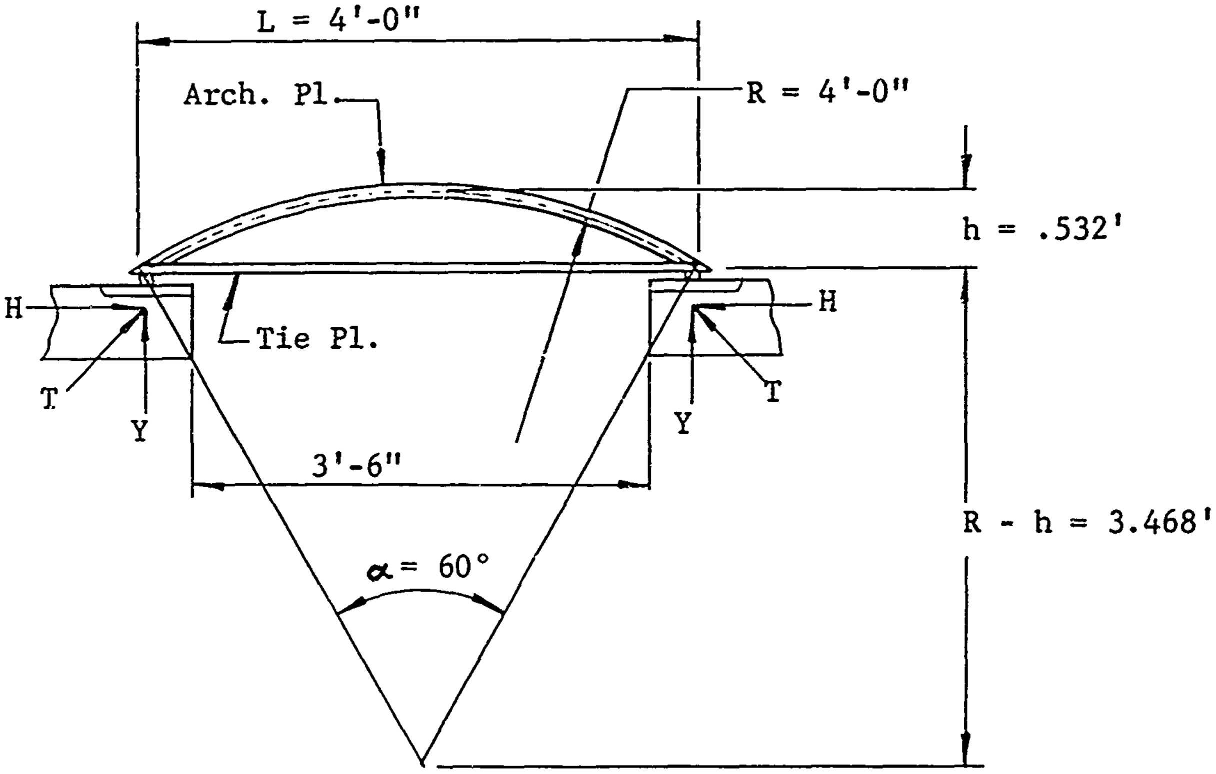


Figure IV-1

$$R = \frac{L/2}{\sin \alpha/2} = \frac{2.00}{0.50} = 4.00$$

$$R - h = R \cos \alpha/2 = 4\ (.867) = 3.468$$

$$h = .532$$

DOOR 60-12-06
Trial No. 1

Design for Direct Loading - Elastic

Assume a D.L.F. = 2.00 $\qquad P_r = .080$ ksi

$T = P_r R = .08\ (2)\ 12\ (4) = 7.68$ k/in.

$V = P_r R \text{ Sin } \alpha/2 = .08\ (2)\ 12\ (4)\ .5 = 3.84$ k/in.

$H = P_r R \text{ Cos } \alpha/2 = .08\ (2)\ 12\ (4)\ .867 = 6.66$ k/in.

Required Thickness

Arch Plate $\quad t = \dfrac{7.68}{41.6} = .185 \qquad$ Try 3/16" plate

Tie Plate $\quad t_1 = \dfrac{6.66}{41.6} = .160 \qquad$ Try 11/64" plate

Shock Velocity

$$U_o = 1117 \left[1 + \frac{6\ P_{so}}{7\ (14.7)} \right]^{\frac{1}{2}}$$

$$U_o = 1117 \left[1 + \frac{6\ (25)}{102.9} \right]^{\frac{1}{2}} = 1750 \text{ ft/sec}$$

Time of Pressure Rise

$$t_o = \frac{h}{U_o} = \frac{.532}{1750} = .000304 \text{ sec.}$$

Period of Vibration of Arch Plate

$$T_N = 2\pi \frac{L^2}{C_2} \sqrt{\frac{m}{EI}}$$

$$C_2 = 4 \sin^2 \alpha/2 \left[2/3 \left(\frac{R}{k}\right)^2 + \left(\frac{\pi^2}{\alpha^2} - 1\right)^2 \right]^{\frac{1}{2}}$$

$$k = \sqrt{\frac{I}{A}} = \sqrt{\frac{\frac{12\ (3/16)^3}{12}}{12\ (3/16)}} = \sqrt{\frac{(3/16)^2}{12}} = .0541 \text{ in.}$$

$$\frac{R}{k} = \frac{48}{.0541} = 887.2$$

DOOR 60-12-06
Trial No. 1

$\alpha = 60° = \pi/3$ radians $\qquad \pi^2/\alpha^2 = 9$

$$C_2 = 4\,(.5)^2 \left[2/3\,(887.2)^2 + (9-1)^2\right]^{\frac{1}{2}}$$

$$= 1 \left[5.24749\,(10^5) + 64\right]^{\frac{1}{2}} = 724.3$$

$L = 48"$

$E = 30\,(10^6)$ psi

$$I = \frac{bd^3}{12} = \frac{1\,(3/16)^3}{12} = .000549 \text{ in}^4/\text{in}$$

$$W = 490\,\left(\frac{3/16}{12}\right) = 7.6 \text{ psf}$$

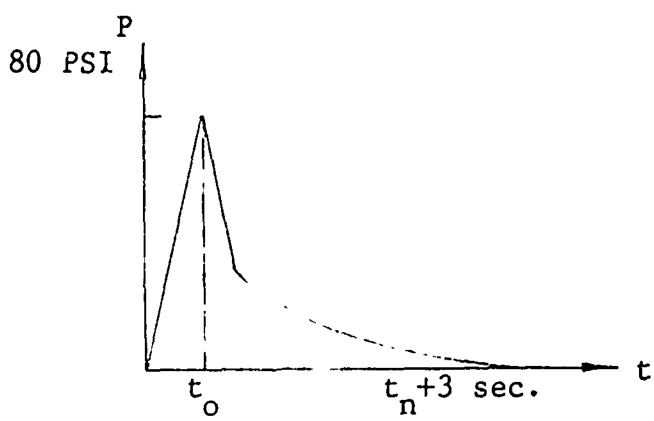
$$m = \frac{7.6}{32.2\,(12)\,144} = .000138\ \#\text{sec}^2/\text{in}^3$$

$$T_n = 2\pi\,\frac{(48)^2}{724.3}\,\sqrt{\frac{.000138}{30\,(10^6)\,.000549}}$$

$$= 19.98\,\sqrt{8.38\,(10^{-10})} = .001828$$

Dynamic Response of Arch Plate

The loading curve is assumed to have a triangular shape as shown below.



$$\frac{t_o}{T_n} = \frac{.000304}{.001828} = .16 \qquad \text{D.L.F.} = 1.95 \cong 2 \qquad \text{Section O.K.}$$

(The David W. Taylor Model Basin, USN, "Effects of Impact on Simple Elastic Structures". Report 481, April 1942, Fig. 18)

DOOR 60-12-06
Trial No. 1

Buckling

$$P_cR = \frac{EI}{R^3}(k^2 - 1)$$

$$k = 8.5 \text{ for } \alpha = 60°$$

$$P_cR = \frac{30\ (10^6)\ .000549}{(48)^3} \left[(8.5)^2 - 1\right]$$

$$= .1489 \left[71.25\right] = 10.6 \text{ psi} \qquad 80\ (2) = 160 \text{ psi} \quad \text{No Good}$$

3/16" plate O.K. for elastic direct loading, but not good for buckling. Try 1/2" plate for buckling.

$$I = \frac{bd^3}{12} = \frac{1\ (1/2)^3}{12} = .0104$$

$$P_cR = \frac{30\ (10^6)\ .0104}{(48)^3} \left[(8.5)^2 - 1\right]$$

$$= 2.82 \left[71.25\right] = 201 \text{ psi} \qquad 80\ (2) = 160 \text{ psi} \qquad \text{O.K.}$$

Use 1/2" arch plate
Use 11/64" tie plate

CALCULATIONS

1-WAY SPAN DOOR
BUILT-UP DESIGN
SIMPLY SUPPORTED 4 SIDES
3'-6" x 7'-0", 50 PSI

TRIAL NO. 2

ELASTO-PLASTIC
DOOR NO. 60-12-07
CALCULATIONS BY T.A.
CHECKED BY H.S.

GIVEN:

Assumed Beam		=	5 x 5 WF 16#
T	= Load Duration	=	.050 Sec.
P_r	= Peak Reflected Pressure	=	197 PSI
W	= Total Weight of Beam	=	58.6 Lbs.
A	= Area of Beam (Width × Span)	=	220.5 Sq. In.
L	= Span Length of Beam	=	3-1/2 Feet
S	= Section Modulus of Beam	=	8.53 Inch^3
I	= Moment of Inertia of Beam	=	21.3 Inch^4
K_{LM_e}	= Elastic Mass Constant	=	.780
K_{LM_p}	= Plastic Mass Constant	=	.667

FIND:

1. MAXIMUM ELASTIC DEFLECTION (FEET)

$$X_{el} = .0017333 \times \frac{L^2 \times S}{I} = .001733 \times \frac{3.5^2 \times 8.53}{21.3}$$

$$= .0017333 \times 4.91 = \underline{.008511}$$

2. NATURAL PERIOD (SECONDS)

$$T_n = 6.2832 \times \sqrt{\frac{M_e}{K_1}}$$

$$= 6.2832 \times \sqrt{\frac{.001420}{7949}}$$

$$= 6.2832 \times \sqrt{.000000178638}$$

$$= 6.2832 \times .00042265 = \underline{.00266}$$

3. EQUIVALENT MASS (ELASTIC) (KIP-SEC^2/FT.)

$$M_e = \frac{W \times K_{LM_e}}{32,200} = \frac{58.6 \times .78}{32,200} = \underline{.001420}$$

4. EQUIVALENT MASS (PLASTIC) (KIP-SEC^2/FT.)

$$M_p = W \times 20.704 \times 10^{-6} = \underline{.001213}$$

5. STIFFNESS FACTOR (KIP/FOOT)

$$K_1 = 16,000 \times \frac{I}{L^3} = 16,000 \times \frac{21.3}{42.875} = \underline{7,949}$$

6. MAX. ELASTIC RESISTANCE (KIP LB)

$$R_{el} = 27.7333 \times \frac{S}{L} = 27.7333 \times \frac{8.53}{3.5} = \underline{68}$$

7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. $\frac{Tn}{10} = \frac{.00266}{10} = \underline{.000266}$

b. $\triangle t = \underline{.0002}$

c. $(\triangle t)^2 = \underline{4 \times 10^{-8}}$

d. $P_o = \frac{P_r \times A}{1{,}000} = \frac{197 \times 220.5}{1{,}000}$ KIP $\underline{43.4}$

e. $P_1 = P_o(1 - \frac{\triangle t}{.05}) = 43.4\ (1 - \frac{.0002}{.05}) = \underline{43.2}$

f. $P_o - P_1 = 43.4 - 43.2 = \underline{.2}$

g. $a_o = \frac{1}{M_e} (\frac{P_o}{2} + \frac{P_1 - P_o}{6}) = \frac{1}{.001420} (\frac{43.4}{2} - \frac{.2}{6})$

$= \underline{15{,}253}$

h. $X_1 = a_o X (\triangle t)^2 = 15{,}253 \times (4 \times 10^{-8}) = \underline{.000610}$

i. $\frac{(\triangle t)^2}{M_e} = \frac{4 \times 10^{-8}}{.001420} = \underline{2817 \times 10^{-8}}$

PLASTIC RANGE

a. $\triangle t = .0002$

b. $(\triangle t)^2 = 4 \times 10^{-8}$

c. $\frac{(\triangle t)^2}{M_p} = \frac{4 \times 10^{-8}}{.001213} = \underline{3298 \times 10^{-8}}$

ACCELERATION IMPULSE EXTRAPOLATION TABLE

X_{el} = .008511 R_{el} = 68 K_1 = 7949

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{m}$	$A_n(\Delta t)^2$ (Feet)	$2X_n$ (Feet)	X_{n-1} (Feet)	X_{n+1} (Feet)	Remarks
0	0	43.4	--	--	$10^{-8} \times 2817$	.000610	0	0	0	
1	.0002	43.2	4.8	38.4	"	.001082	.001220	0	.000610	
2	.0004	43.0	18.3	24.7	"	.000696	.004604	.000610	.002302	
3	.0006	42.8	37.3	5.5	"	.000155	.009380	.002302	.004690	
4	.0008	42.6	57.5	-14.9	"	-.000418	.014466	.004690	.007233	
5	.0010	42.4	68.0	-25.6	$10^{-8} \times 3298$	-.000844	.018716	.007233	.009358	
6	.0012	42.2	6810	-25.8	"	-.000850	.021278	.009358	.010639	
7	.0014	42.0	68.0	-26.0	"	-.000857	.022140	.010639	.011070 ←	MAX.
8	.0016	41.8	64.6	-22.8	"	-.000752	.021288	.011070	.010644	
9	.0018	41.6	55.2	-13.6	"	-.000449	.018932	.010644	.009466	
10	.0020	41.4	42.3	- 0.9	"	-.000030	.015678	.009466	.007839	
11	.0022	41.2	29.1	12.1	"	.000399	.012364	.007839	.006182	
12	.0024	41.0	19.1	21.9	"	.000722	.009848	.006182	.004924	
13	.0026	40.8	14.9	25.9	"	.000854	.008776	.004924	.004388	
14									.004706	
15										
16										
17										
18										
19										
20										
21										

<u>RESULTS</u>

Maximum Deflection = .011070
Elastic Deflection = .008511
Permanent Deflection = .002559

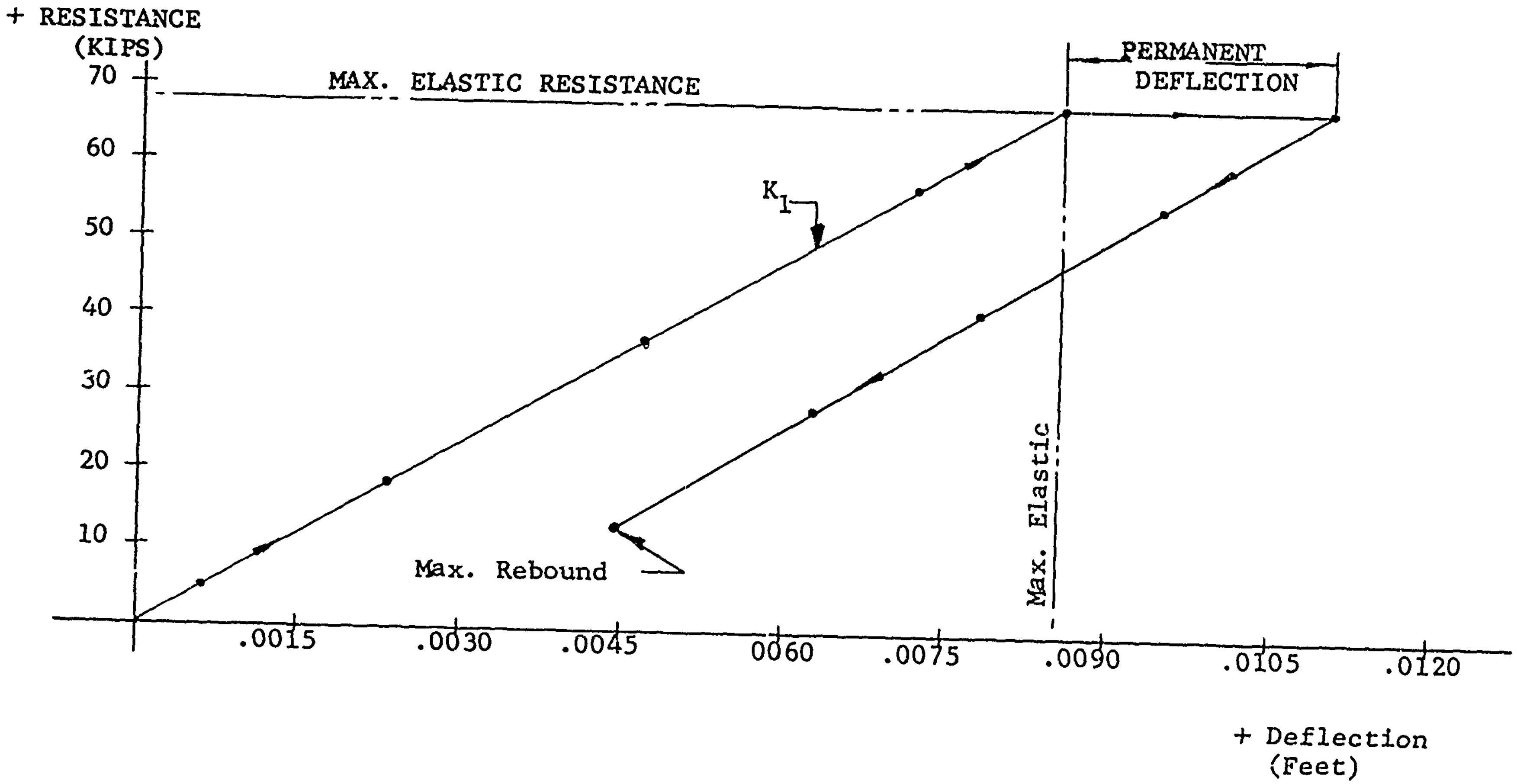
At .5" allowable total deflection - will take 16.3 max. blasts

T = .05

R_x TABLE

Maximum R_x to Minus R_{el}

$R_{Max.}$ −	[($X_{Max.}$ −	X_x) ÷	×	K_1 ÷	]	= R_x
68	.011070	.010694	.000426	7,949	3.4	64.6
"	"	.009466	.001604	"	12.8	55.2
"	"	.007839	.003231	"	25.7	42.3
"	"	.006182	.004888	"	38.9	29.1
"	"	.004924	.006146	"	48.9	19.1
"	"	.004388	.006682	"	53.1	14.9



Scale:	Approved by:	
DOOR NO. 60-12-07 - T2 1-WAY SPAN, BUILT-UP		
LOAD DURATION - .050 Sec.		

7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. $\frac{T_n}{10} = \frac{.00266}{10} = .000266$

b. $\triangle t = .0002$

c. $(\triangle t)^2 = 4 \times 10^{-8}$

d. $P_o = \frac{P_r \text{ X } A}{1{,}000} = \frac{197 \times 220.5}{1{,}000}$ KIP 43.4

e. $P_1 = P_o(1 - \frac{t}{.009}) = 43.4\ (1 - \frac{.0002}{.009}) = 42.4$

f. $P_o - P_1 = 43.4 - 42.4 = 1$

g. $a_o = \frac{1}{M_e} (\frac{P_o}{2} + \frac{P_1 - P_o}{6}) = \frac{1}{.001420} (\frac{43.4}{2} - \frac{1}{6})$

$= 15{,}162$

h. $X_1 = a_o X (\quad t)^2 = 15{,}162 \times (4 \times 10^{-8}) = .000606$

i. $\frac{(\triangle t)^2}{M_e} = \frac{4 \times 10^{-8}}{.001420} = 2{,}817 \times 10^{-8}$

PLASTIC RANGE

a. $\triangle t = .0002$

b. $(\triangle t)^2 = 4 \times 10^{-8}$

c. $\frac{(\triangle t)^2}{M_p} = \frac{4 \times 10^{-8}}{.001213} = 3{,}298 \text{ x } 10^{-8}$

ACCELERATION IMPULSE EXTRAPOLATION TABLE

X_{el} = .008511 K_1 = 7949

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{M}$	$A_n(\Delta t)^2$ (Feet)	$2 X_n$ (Feet)	X_{n-1} (Feet)	X_{n+1} (Feet)	Remarks
0	0	43.4	--	--	$10^{-8} \times 2817$	.000606	0	0	0	
1	.0002	42.4	4.8	37.6	"	.001059	.001212	0	.000606	
2	.0004	41.4	18.1	23.3	"	.000656	.004542	.000606	.002271	
3	.0006	40.4	36.5	3.9	"	.000106	.009184	.002271	.004592	
4	.0008	39.4	55.8	-16.4	"	-.000462	.014038	.004592	.007019	
5	.0010	38.4	68.0	-29.6	$10^{-8} \times 3298$	-.000976	.017968	.007019	.008984	
6	.0012	37.4	68.0	-30.6	"	-.001009	.019946	.008984	.009973	← MAX.
7	.0014	36.4	67.8	-31.4	"	-.001036	.019906	.009973	.009953	
8	.0016	35.4	59.4	-24.0	"	-.000792	.017794	.009953	.008897	
9	.0018	34.4	44.8	-10.4	"	-.000343	.014098	.008897	.007049	
10	.0020	33.4	27.3	6.1	"	.000201	.009716	.007049	.004858	
11	.0022	32.4	11.5	20.9	"	.000689	.005736	.004858	.002868	
12	.0024	31.4	1.2	30.2	"	.000996	.003134	.002868	.001567	
13	.0026	30.4	- 1.2	31.6	"	.001042	.002524	.001567	.001262	
14	.0028							.001262	.001999	
15										
16										
17										
18										
19										
20										
21										

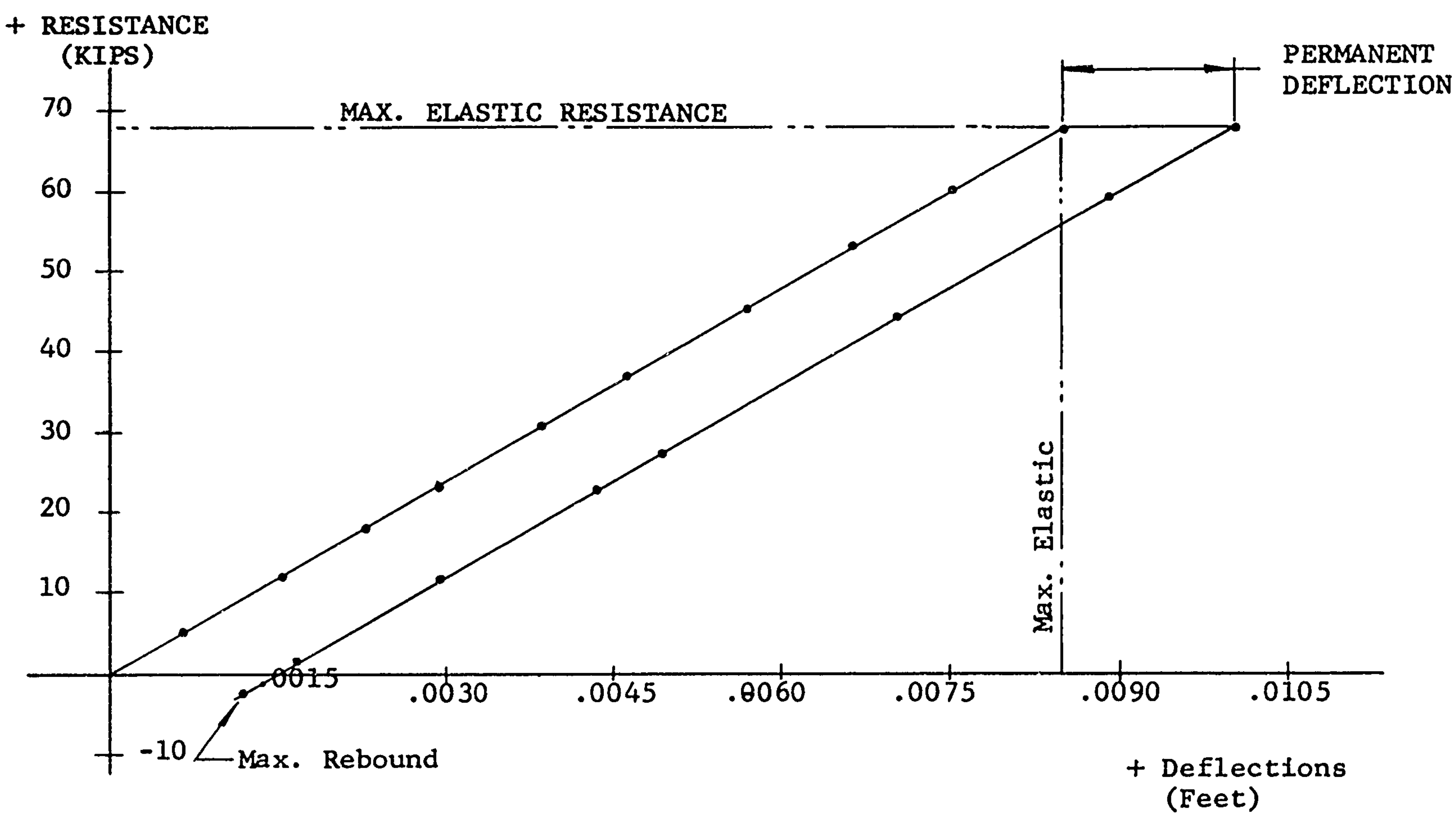
Ratio $= \frac{1.2}{68} =$

Max. Rebound =

R_x TABLE

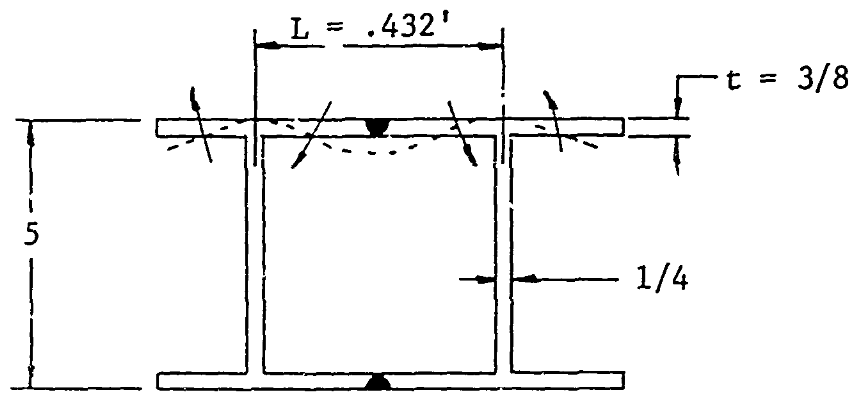
Maximum R_x to Minus R_{el}

$R_{Max.}$ −	$\left[\left(X_{Max.}\right.\right.$ −	$\left.X_x\right)$ =	×	K_1 =	$\left.\right]$ =	R_x
68	.009973	.009953	.000020	7,949	0.2	67.8
"	"	.008897	.001076	"	8.6	59.4
"	"	.007049	.002924	"	23.2	44.8
"	"	.004858	.005115	"	40.7	27.3
"	"	.002868	.007105	"	56.5	11.5
"	"	.001567	.008406	"	66.8	1.2
"	"	.001262	.008711	"	69.2	- 1.2



Scale:	Approved by:	
DOOR NO. 60-12-07 - T2 1-WAY SPAN, BUILT-UP		
LOAD DURATION - .009 Sec.		

CALCULATION FOR LOCAL CONDITION



1. $M_{\mathbb{C}} = M_s = 1/4 \times 41.6 \times t^2 = 1/4 \times 41.6 \times .141$

$= 1.4$ K in/in

2. $\sum M = \dfrac{2\ M}{12} = \dfrac{1}{6} \times \dfrac{1.4}{6} = .233$ K-ft/in

3. $R = \dfrac{8M}{L} = \dfrac{8 \times .233}{.432} = 4.3$ K/in

4. $F = \dfrac{12\ P_r \times L \times 1 \text{ (per inch)}}{1{,}000} = \dfrac{(12)(197)(432)}{1{,}000} = 1$ K/in

5. $\text{D.L.F.} = \dfrac{R}{F} = \dfrac{4.3}{1} = 4.3 > 2$ (Member remains elastic)

CHECK FOR LOCAL BUCKLING OF ONE-WAY BEAMS

Beam = 5 x 5 WF @ 16#

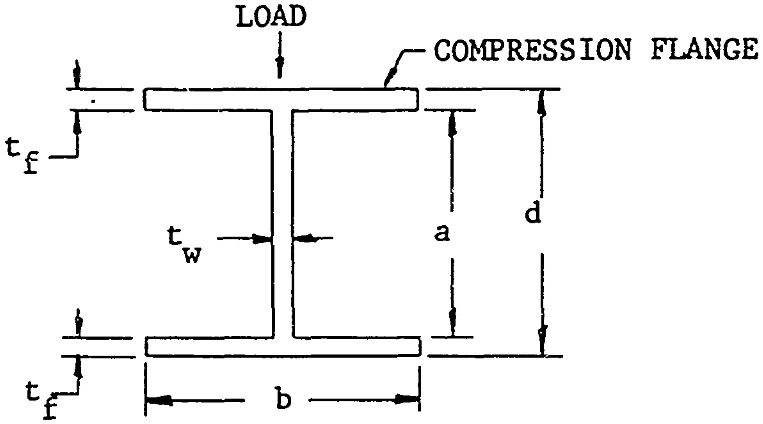
$a = 4\text{-}1/4$

$b = 5\text{-}3/16$

$d = 5$

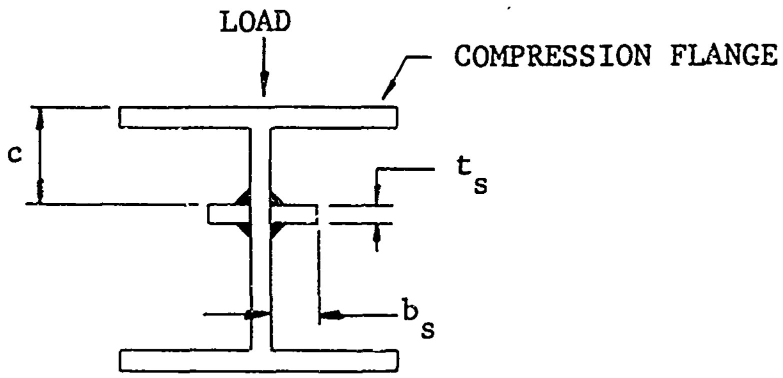
$t_f = 3/8$

$t_w = 1/4$



$$\text{Web Ratio} = \frac{a}{t_w} = \frac{4.25}{.25} = 17$$

WEB REINFORCEMENT (WHEN REQUIRED)



Length of Stiffeners

Locate symmetrical with mid-point of door

CHECK FOR LATERAL-TORSIONAL BUCKLING

GIVEN:

K^1 = 0.51

L = Span = 42

d = Depth of Beam = 5.000

b = Width of Flange = 5.184

T_f = Thickness of Flange = .360

1. $$\frac{K^1\ Ld}{b\ T_f} = \frac{.51 \times 42 \times 5.000}{5.184 \times .360}$$

$$= \frac{107.100}{1.866}$$

$$= 57.4 < 100 \qquad \text{O.K.}$$

BEARING AREA STRESS

R_m = Maximum Resistance of Door

$$= R_{el} \times \frac{\text{Area of Leaf}}{\text{Area of Beam}} = R_{el} \times \frac{L_2 \times h}{L_2 \times W_b} = R_{el} \times \frac{h}{W_b}$$

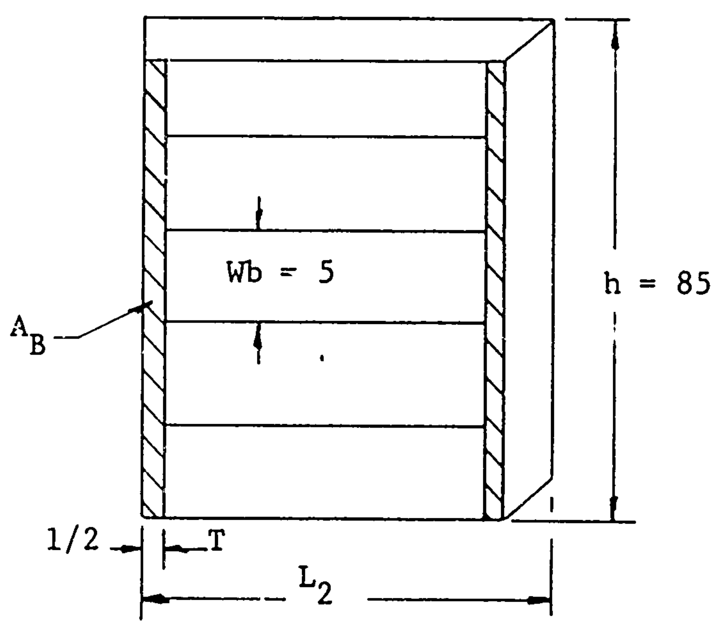
R_{el} = 68,000#

$$R_m = 68,000 \times \frac{85}{5.000} = 1,156,000$$

$$S_b = \text{Bearing Stress} = \frac{R_m}{A_B} = \frac{R_m}{2T{\times}h}$$

$$A_B = 2 \times 1/2 \times 85 = 85 \text{ in}^2$$

$$S_b = \frac{1,156,000}{85} = 13,600 < 30,000 \text{ PSI} \quad \text{OK}$$



STRIKER THICKNESS CALCULATIONS

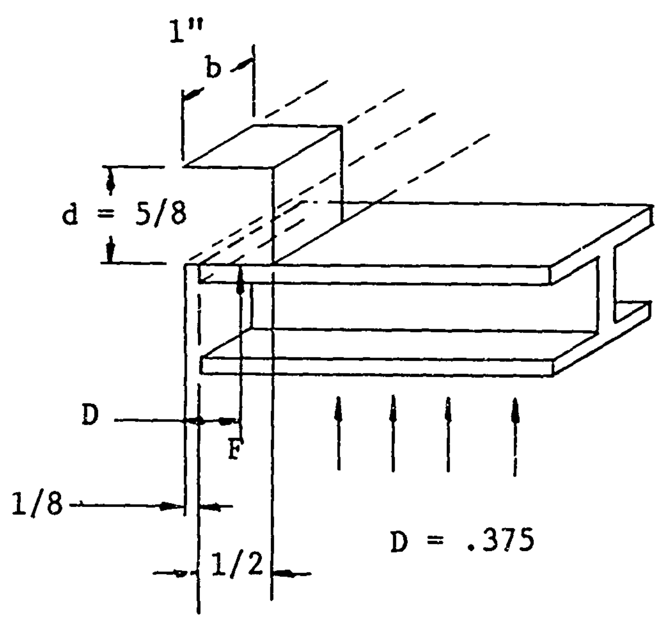
Take a 1" wide typical strip.

Force per Lineal Inch = $F = \dfrac{Rm}{2 \times L_1}$ (see p. 26m)

$= S_B \times T = 13{,}600 \times .500 = 6{,}800$

Bending Moment = $M = F \times D = 6{,}800 \times .372 = 2{,}550$

Thickness = $d = \sqrt{\dfrac{6M}{S_B^{\ *}}} = \sqrt{.367788} = .60696$ USE 1"



$^*S_B$ = Allowable Bending Stress #A-7 Steel = 41,600

REBOUND LOAD CALCULATION FOR LOCK BOLTS

Consider rebound resisted equally by "dead latch" and lock bolts.

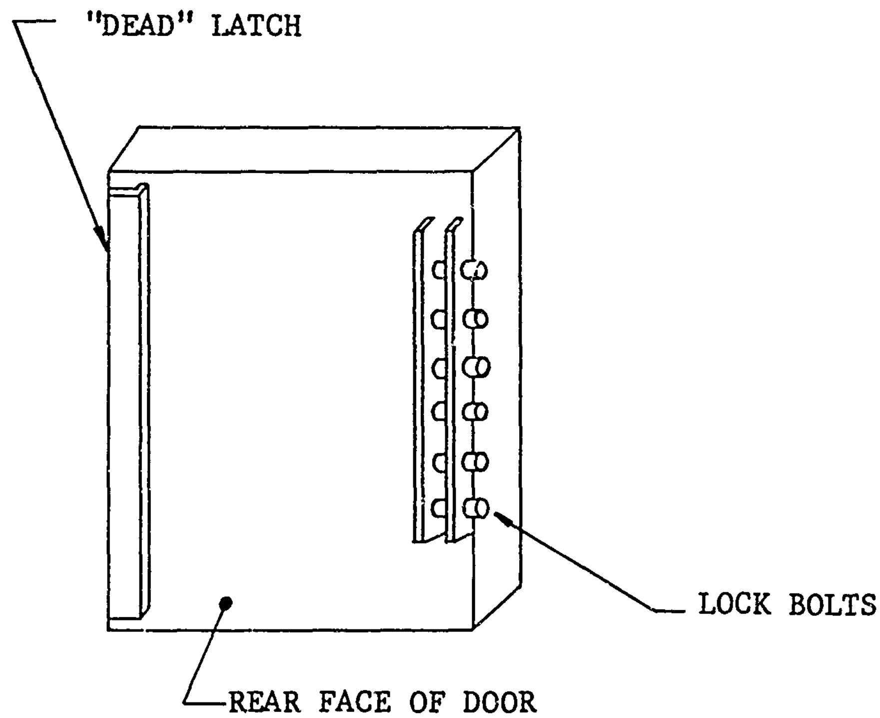
Then:

$$.25\,P_m$$

$$\text{Rebound force per bolt} = P = \frac{\text{Max. Rebound Force}}{2 \times \text{no. of lock bolts}}$$

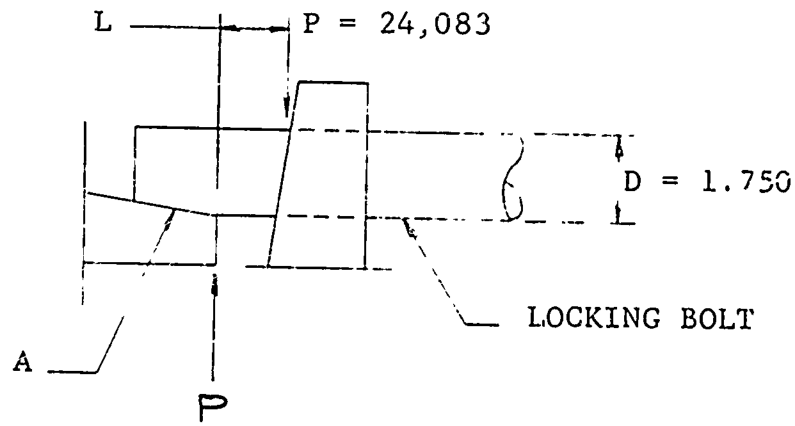
$$= \frac{289{,}000}{12} = 24{,}083$$

Maximum total rebound force is obtained from rebound calculations.



LOCK BOLT CALCULATIONS - REBOUND - BLAST DOOR

MAX. L = .909



MIN. A = .803

P = Equiv. Static Force per Bolt in Pounds

L = Length in inches

D = Diameter in inches

A = Bearing area in sq. in.

1. Vertical Shear $= \dfrac{4\ P}{\pi \times D^2} = \dfrac{4 \times 24{,}083}{3.1416 \times 3.0625} = \dfrac{96{,}332}{9.62} = 10{,}014$

2. Horiz. Shear $= \dfrac{16\ P}{3\pi \times D^2} = \dfrac{16 \times 24{,}083}{3 \times 3.1416 \times 3.0625} = \dfrac{385{,}328}{28.86} = 13{,}352$

3. Bending Stress $= \dfrac{32 \times P \times L}{\pi \times D^3} = \dfrac{32 \times 24{,}083 \times .875}{3.1416 \times 5.359} = \dfrac{674{,}324}{16.84} = 40{,}043$

4. Bearing Stress $= \dfrac{P}{A} = \dfrac{24{,}083}{1.898} = 12{,}689$

Allowable Stresses - #A-7 Steel:

1. 21,000 PSI
2. 21,000 PSI
3. 41,600 PSI
4. 30,000 PSI

CALCULATIONS FOR RADIAL-THRUST BEARINGS IN LOWER HINGE*

RPM $\leqq$ 50 F_a/F_r .65

Rotating Inner Ring

Thrust Load	=	F_a	=	2,076
Radial Load	=	F_r	=	746
Rotation Factor	=	V	=	1
Thrust Factor	=	Y	=	1.45
Radial Factor	=	X	=	.67

P = Equivalent Load

$$P = XV\,F_r + Y\,F_a$$

$$= .67\,F_r + 1.45\,F_a$$

$$= (.67 \times 746) + (1.45 \times 2{,}076)$$

$$= 500 + 3{,}010$$

$$= 3{,}510$$

$$\frac{C}{P} \geqq 1.0$$

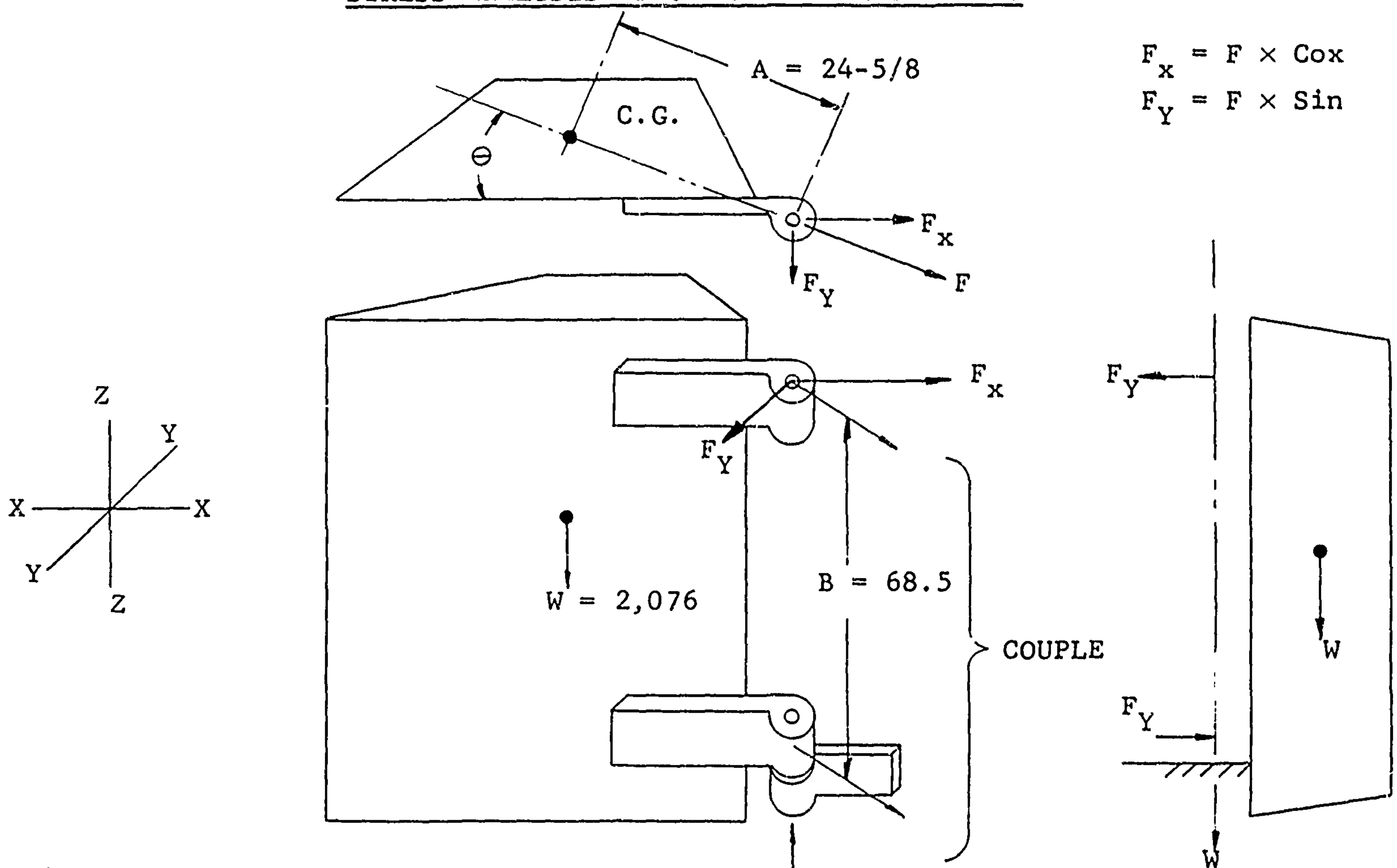
$\therefore$ Minimum bearing is SKF #5303 or equivalent.
Use SKF bearing #5304 or equivalent.

* Formula shown is for Series 5200 and 5300 double row, deep groove SKF bearings. Series #5300 preferred. For other design bearings, check formula.

STRESS ANALYSIS DIAGRAM - HINGE BEARINGS

$F_x = F \times Cox$

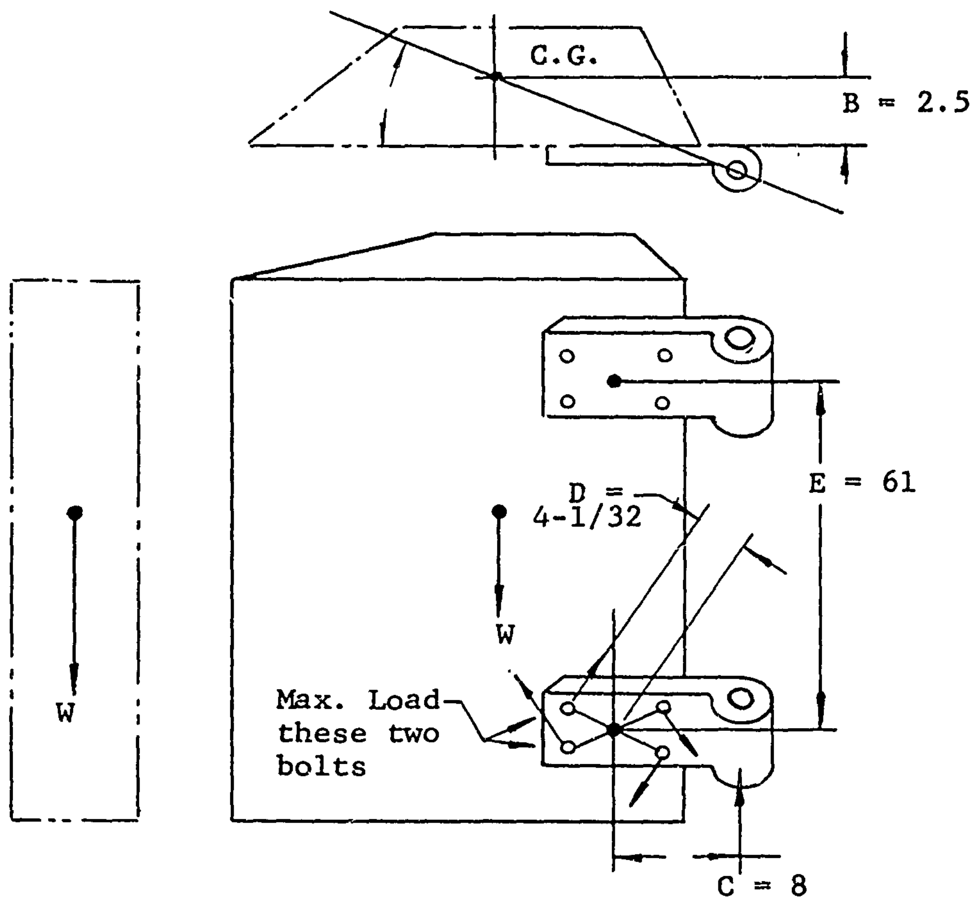
$F_Y = F \times Sin$



$W \times A = F \times B$

$$F = \frac{W \times A}{B} = \frac{2{,}076 \times 24.625}{68.5} = \frac{51{,}121.5}{68.5} = 746$$

STRESS ANALYSIS DIAGRAM - HINGE BOLTS (NO SAFETY FACTOR)



W = Weight = 2,076

(Lower 4 bolts)
Min. Resistance to Twisting Moment per Bolt:

$$R_M = \frac{W \times C}{4 \times D} = \frac{2{,}076 \times 8}{4 \times 4.033} = \frac{16{,}608}{16.132} = 1{,}029$$

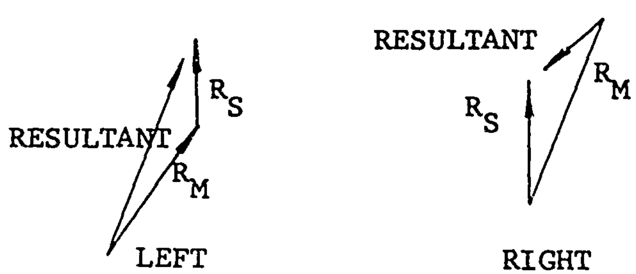
(Upper 4 Bolts only)
Min. Resistance to Tension per Bolt:

$$R_T = \frac{W \times B}{4 \times E} = \frac{2076 \times 2.5}{4 \times 61} = \frac{5190}{244} = 21.27$$

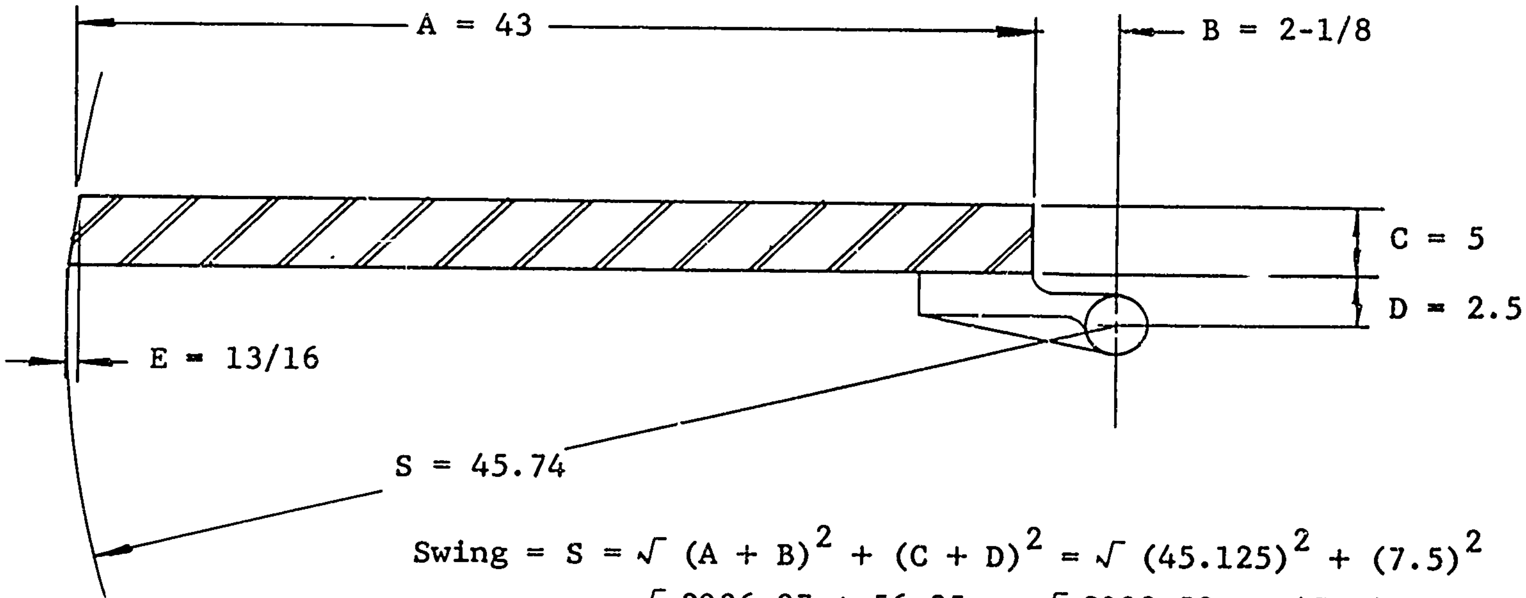
(Lower 4 Bolts only)
Min. Resistance to Shear per Bolt:

$$R_S = \frac{W}{4} = \frac{2076}{4} = 519$$

VECTOR ADDITION FORCES ON LOWER BOLTS



CALCULATIONS - DOOR SWING AND DOOR TAPER



$$\text{Swing} = S = \sqrt{(A + B)^2 + (C + D)^2} = \sqrt{(45.125)^2 + (7.5)^2}$$

$$= \sqrt{2036.27 + 56.25} = \sqrt{2092.52} = 45.74$$

$$\text{Taper} = E = \frac{C^2 + (C \times D)}{(A + B)} = \frac{24 + 12.5}{45.125} = \frac{27.500}{45.125} = .831 \qquad \text{Use } 13/16$$

CALCULATIONS

TRIAL NO. 2

1-WAY SPAN DOOR
BUILT-UP DESIGN
SIMPLY SUPPORTED 2 SIDES
PARTIALLY LOADED OVER FULL SPAN
14'-0" x 18'-0", 50 PSI

ELASTO-PLASTIC
DOOR NO. 60-12-19
CALCULATIONS BY T.A.
CHECKED BY H.S.

GIVEN:

Assumed Beam		=	24 WF @ 145
T	= Load Duration	=	.050 Sec.
P_r	= Peak Reflected Pressure	=	197 PSI
W	= Total Weight of Beam	=	2465 Lbs.
A	= Area of Beam (Width × Span)	=	2268 Sq. In.
L_2	= Span Length of Beam	=	17 Feet
S	= Section Modulus of Beam	=	3725 Inch^3
I	= Moment of Inertia of Beam	=	4561 Inch^4
K_{LM_e}	= Elastic Mass Constant	=	.67
K_{LM_p}	= Plastic Mass Constant	=	.57
L_1	= Loaded Portion of Beam	=	14 Feet

Figure IV-3

FIND:

1. MAXIMUM ELASTIC DEFLECTION (FEET)

$$X_{el} = .000346666 \times \frac{S}{I}\left(\frac{8\,L_2^3 - 4\,L_1^2 L_2 + L_1^3}{2\,L_2 - L_1}\right) =$$

$$(.000346666)(.081671)\left(\frac{39304 - 13328 + 2744}{20}\right) =$$

$$.000346666 \times 94.869034 = \underline{.032888}$$

2. NATURAL PERIOD (SECONDS)

$$T_n = 6.2832 \times \sqrt{\frac{M_e}{K_1}}$$

$$= 6.2832 \times \sqrt{\frac{.051290}{15706}}$$

$$= 6.2832 \times \sqrt{.000003265631}$$

$$= 6.2832 \times .001807 = \underline{.011354}$$

3. EQUIVALENT MASS (ELASTIC) (KIP-SEC^2/FT.)

$$M_e = \frac{W \times K_{LM_e}}{32,200} = \frac{2465 \times .67}{32,200} = \underline{.051290}$$

4. EQUIVALENT MASS (PLASTIC) (KIP-SEC^2/FT.)

$$M_p = W \times 20.704 \times 10^{-6} = 2465 \times 20.704 \times 10^{-6} = \underline{.051035}$$

5. STIFFNESS FACTOR (KIP/FOOT)

$$K_1 = 80,000 \times \frac{I}{8\ L_2^3 - 4\ L_1^2 L_2 + L_1^3}$$

$$= 80,000 \times \frac{4561}{39304 - 13328 + 2744}$$

$$= 80,000 \times \frac{4561}{23,232} = \underline{15,706}$$

6. MAX. ELASTIC RESISTANCE (KIP LB)

$$R_{el} = \frac{27.7333 \times S}{2\ L_2 - L_1} = \underline{517}$$

7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. $\frac{T_n}{10} = \frac{.01}{10} = \underline{.001}$

b. $\Delta t = \underline{.001}$

c. $(\Delta t)^2 = \underline{1 \times 10^{-6}}$

d. $P_o = \frac{P_r \times A}{1000} = \underline{447 \text{ KIP}}$

e. $P_1 = P_o(1 - \frac{t}{.05}) = 447\ (1 - \frac{.001}{.05}) = \underline{438}$

f. $P_o - P_1 = 447 - 438 = \underline{9}$

g. $a_o = \frac{1}{M_e} (\frac{P_o}{2} + \frac{P_1 - P_o}{6}) = \underline{4,328}$

h. $X_1 = a_o \times (\Delta t)^2 = 4328 \times 10^{-6} \times 1 = \underline{.004328}$

i. $\frac{(\Delta t)^2}{M_e} = \frac{1 \times 10^{-6}}{.051290} = \underline{19.496 \times 10^{-6}}$

PLASTIC RANGE

a. $\Delta t = .001$

b. $(\Delta t)^2 = 1 \times 10^{-6}$

c. $\frac{(\Delta t)^2}{M_p} = \frac{10^{-6}}{.051035} = \underline{19.594 \times 10^{-6}}$

ACCELERATION IMPULSE EXTRAPOLATION TABLE

X_{el} = .032888 R_{el} = 517 K_1 = 15,706

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{m}$	$A_n(\Delta t)^2$ Feet	$2X_n$ (Feet)	X_{n-1} (Feet)	X_{n+1} (Feet)	Remarks
0	.000	447	0	447	19496×10^{-6}	.004328	0	0	0	
1	.001	438	68	370	"	.007214	.008656	0	.004328	
2	.002	429	249	180	"	.003509	.031740	.004328	.015870	
3	.003	420	486	- 66	"	-.001287	.061842	.015870	.030921	
4	.004	411	517	-106	19594×10^{-6}	-.002077	.089370	.030921	.044685	
5	.005	402	517	-115	"	-.002253	.112744	.044685	.056372	
6	.006	393	517	-124	"	-.002430	.131612	.056372	.065806	
7	.007	384	517	-133	"	-.002606	.145620	.065806	.072810	
8	.008	375	517	-142	"	-.002782	.154416	.072810	.077208	
9	.009	366	517	-151	"	-.002959	.157648	.077208	.078824	
10	.010	357	496	-139	19496×10^{-6}	-.002710	.154962	.078824	.077481	
11	.011	348	432	- 84	"	-.001638	.146856	.077481	.073428	
12	.012	339	343	- 4	"	-.000078	.135474	.073428	.067737	
13	.013	330	252	78	"	.001520	.123936	.067737	.061968	
14	.014	321	186	135	"	.002632	.115438	.061968	.057719	
15	.015	312	160	152	"	.002962	.112204	.057719	.056102	
16	.016	303						.056102	.057448	
17										
18										
19										
20										
21										

<u>RESULTS</u>

Maximum Deflection = .078824
Elastic Deflection = .032888
Permanent Deflection = .045936

Ratio = $\frac{517}{447}$ = 1.16

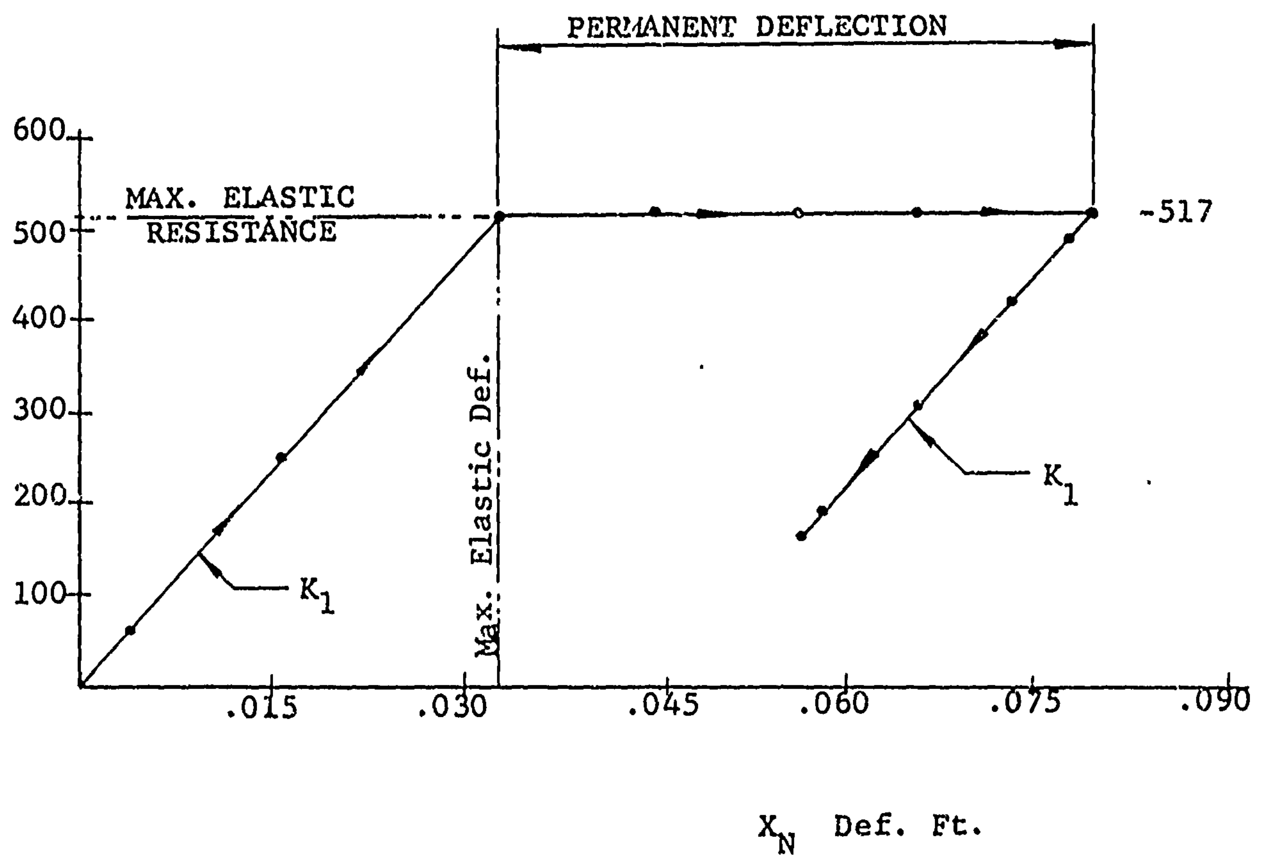
Max. Rebound =

At 3" allowable total deflection - will take 5.4 max. blasts

R_x TABLE

Maximum R_x to Minus R_{el}

$R_{Max.}$ −	[($X_{Max.}$ −	X_x) ÷	×	K_1 ÷	] =	R_x
517	.078824	.077481	.001343	15,706	21	496
"	"	.073428	.005396	"	85	432
"	"	.067737	.011087	"	174	343
"	"	.061968	.016856	"	265	252
"	"	.057719	.021105	"	331	186
"	"	.056102	.022722	"	357	160



Scale:	Approved by:	
DOOR NO. 60-12-19 - T1 24-1/2" thick - 50 PSI Incident Pressure		
LOAD DURATION - .05 Sec.		

7. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC RANGE

a. $\frac{T_n}{10} = .001$

b. $\Delta t = .001$

c. $(\Delta t)^2 = 1 \times 10^{-6}$

d. $P_o = \frac{P_r \text{ X } A}{1{,}000} = 447$ KIP

e. $P_1 = P_o(1 - \frac{\Delta t}{.024}) = 428$ KIP

f. $P_o - P_1 = 447 - 428 = 19$ KIP

g. $a_o = \frac{1}{M_e} \left(\frac{P_o}{2} + \frac{P_1 - P_o}{6} \right) = 4296$

h. $X_1 = a_o \text{ X} (\Delta t)^2 = 4296 \times 1 \times 10^{-6} = .004296$

i. $\frac{(\Delta t)^2}{M_e} = \frac{1 \times 10^{-6}}{.051290} = 19.496 \times 10^{-6}$

PLASTIC RANGE

a. $\Delta t = .001$

b. $(\Delta t)^2 = 1 \times 10^{-6}$

c. $\frac{(\Delta t)^2}{M_p} = 19.594 \times 10^{-6}$

ACCELERATION IMPULSE EXTRAPOLATION TABLE

X_{el} = .032888 R_{el} = 517 K_1 = 15,706

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{m}$	$A_n(\Delta t)^2$ (Feet)	$2X_n$ (Feet)	X_{n-1} (Feet)	X_{n+1} (Feet)	Remarks
0	0	447	0	447	19496×10^{-6}	.004296	0	0	0	
1	.001	428	67	361	"	.007038	.008592	0	.004296	
2	.002	409	245	164	"	.003197	.031260	.004296	.015630	
3	.003	390	474	- 84	"	-.001638	.060322	.015630	.030161	
4	.004	371	517	-146	19594×10^{-6}	-.002861	.086108	.030161	.043054	
5	.005	352	517	-165	"	-.003233	.106172	.043054	.053086	
6	.006	333	517	-184	"	-.003605	.119770	.053086	.059885	
7	.007	314	517	-203	"	-.003978	.126158	.059885	.063079	
8	.008	295	505	-210	19496×10^{-6}	-.004094	.124590	.063079	.062295	
9	.009	276	428	-152	"	-.002963	.114834	.062295	.057417	
10	.010	257	305	- 48	"	-.000936	.099152	.057417	.049576	
11	.011	238	167	71	"	.001384	.081598	.049576	.040799	
12	.012	219	51	168	"	.003275	.066812	.040799	.033406	
13	.013	200	- 14	214	"	.004172	.058576	.033406	.029288	
14	.014	181						.029288	.029342	
15										
16										
17										
18										
19										
20										
21										

RESULTS

Maximum Deflection = .063079
Elastic Deflection = .032888
Permanent Deflection = .030191

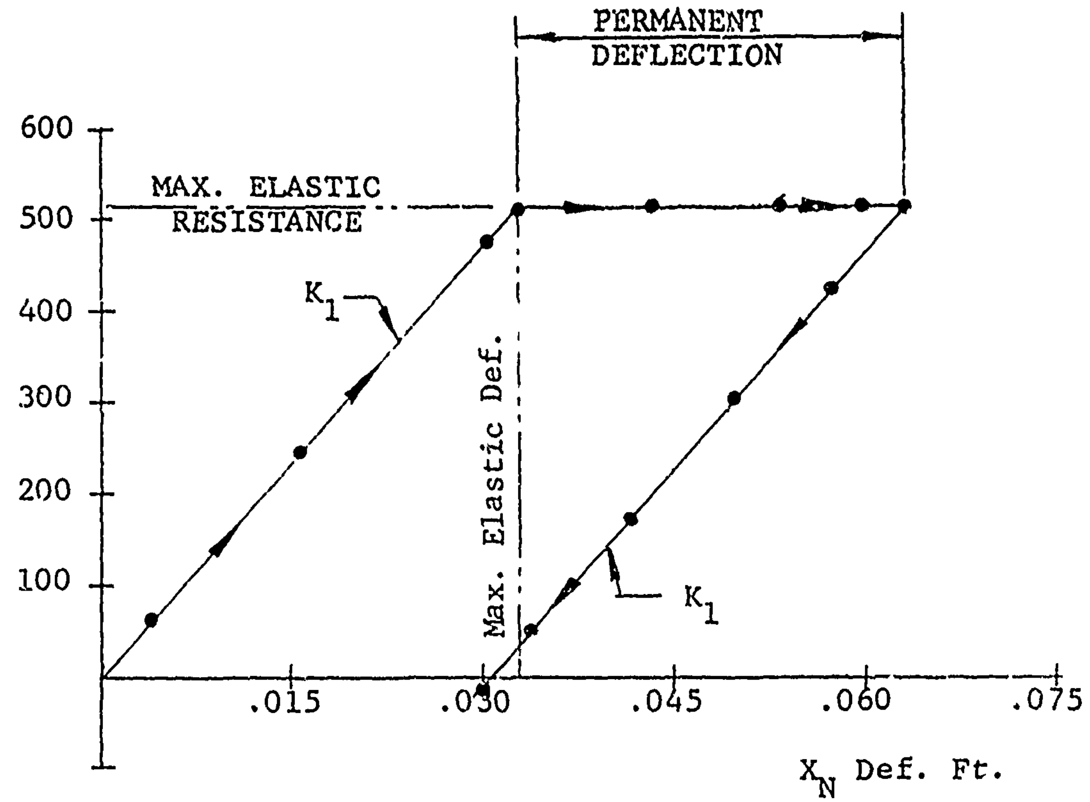
Ratio = $\frac{517}{447}$ = 1.16
Max. Rebound = -14 Kips

At 3" allowable total deflection - will take___ max. blasts

R_x TABLE

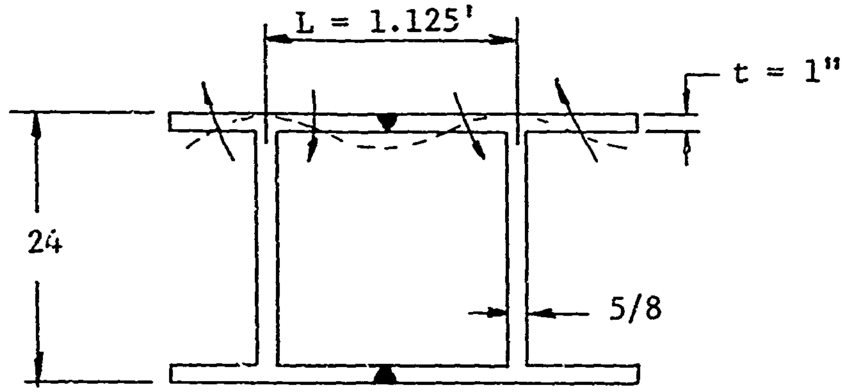
Maximum R_x to Minus R_{el}

$R_{Max.}$ −	[($X_{Max.}$ −	X_x) =	×	K_1 =	]	= R_x
517	.063079	.062295	.000784	15,706	12	505
"	"	.057417	.005662	"	89	428
"	"	.049576	.013503	"	212	305
"	"	.040799	.022280	"	350	167
"	"	.033406	.029673	"	466	51
"	"	.029288	.033791	"	531	- 14



Scale:	Approved by:	
DOOR NO. 60-12-19 - T1 24-1/2" thick - 50 PSI Incident Pressure		
LOAD DURATION - .024 Sec.		

CALCULATION FOR LOCAL CONDITION



1. $M_L = M_s = 1/4 \times 41.6 \times t^2 = 1/4 \times 41.6 \times 1$

$= 10.4$ K in/in

2. $\sum M = \dfrac{2\ M}{12} = \dfrac{1}{6} \times 10.4 = 1.73$ K-ft/in

3. $R = \dfrac{8\ M}{L} = \dfrac{1.73 \times 8}{1.125} = 12.3$ K/in

4. $F = \dfrac{12\ P_r \times L \times 1 \text{ (per inch)}}{1{,}000} = \dfrac{12 \times 197 \times 1.125}{1{,}000} = 2.66$ K/in

5. D.L.F. $= \dfrac{R}{F} = \dfrac{12.3}{2.66} = 4.6 \quad > 2$ (Member remains elastic)

CHECK FOR LOCAL BUCKLING OF ONE-WAY BEAMS

Beam = 24 WF @ 145

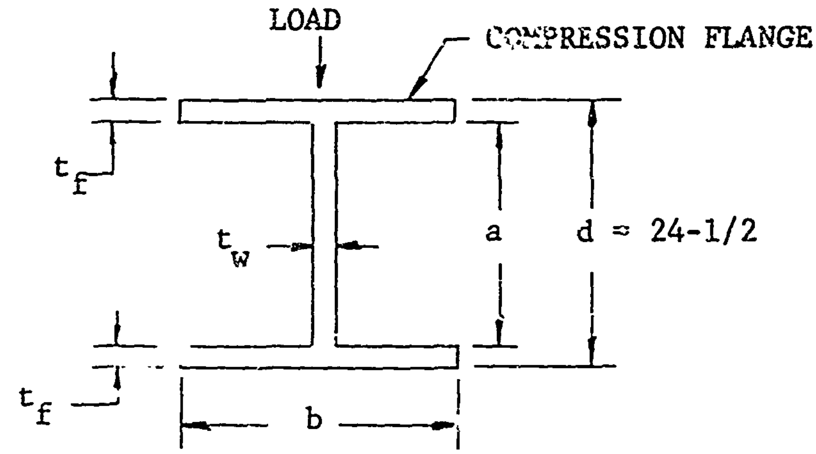
a = 22-1/2

b = 13-1/2

d = 24-1/2

t_f = 1

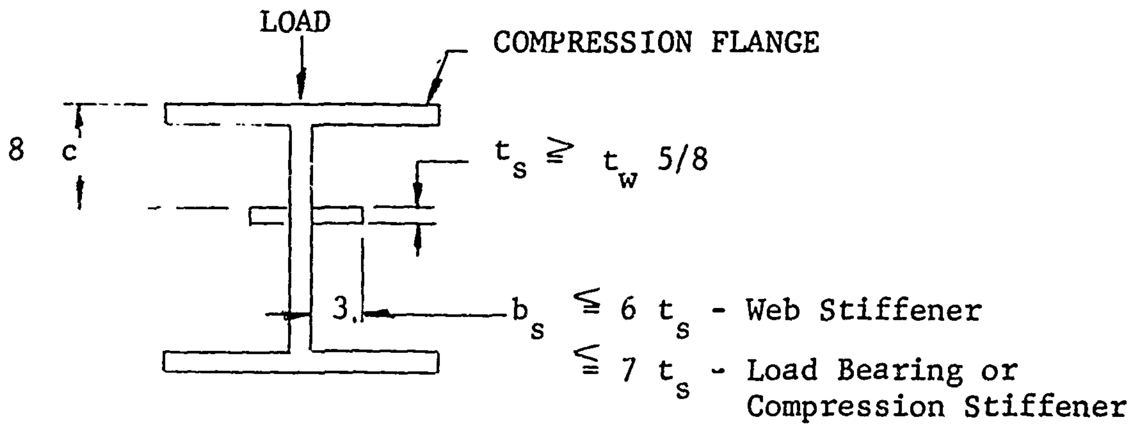
t_w = .625



1. Compression Flange Ratio $= \dfrac{b}{t_f} = 13.5$

2. Web Ratio $= \dfrac{a}{t_w} = \dfrac{22.5}{.625} = 36$

WEB REINFORCEMENT (When required)



Length of Stiffeners

Locate symmetrical with mid-point of door

CHECK FOR LATERAL-TORSIONAL BUCKLING

GIVEN:

K^1 = .51

L = Span = 204

d = Depth of Beam = 24-1/2

b = Width of Flange = 13-1/2

T_f = Thickness of Flange = 1

1. $$\frac{K^1\ Ld}{b\ T_f} = \frac{.51 \times 204 \times 24\text{-}1/2}{13.5 \times 1} = 188.8$$

DOOR 60-12-19

BLAST COLUMN DESIGN

PLAN SECTION OF COLUMN

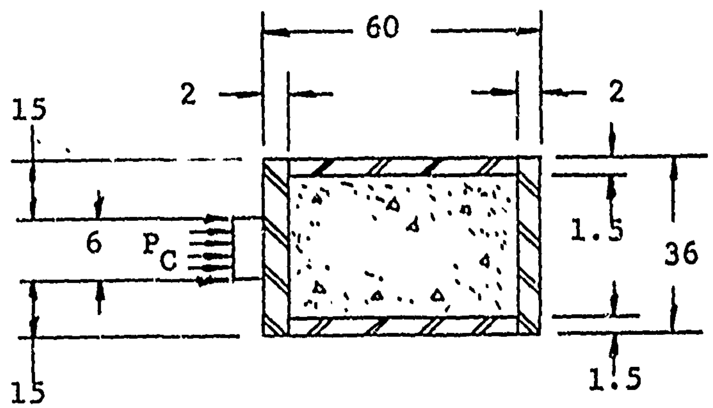
P_T = Total Blast Load

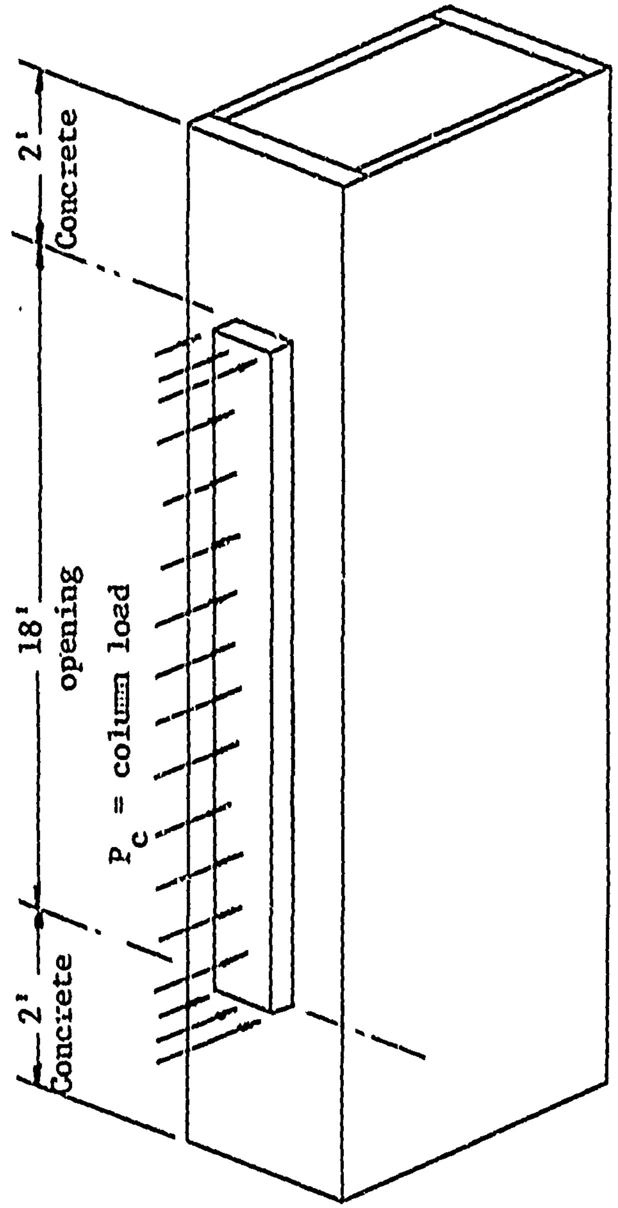
P_c = Column Load = $\frac{P_T}{2}$

$$P_T = H \times W \times P_R \times \frac{R_{EL}}{P_{Max.}} \times 144 = 18 \times 14 \times 197 \times 1.2 \times 144$$

$$= 8,578 \text{ KIPS}$$

$$P_c = \frac{P_T}{2} = \frac{8,578}{2} = 4,289 \text{ KIPS}$$





BLAST COLUMN DESIGN

A. COLUMN LOADING - NO ALLOWANCE FOR CONCRETE

$S = \frac{M}{Z}$ M = Maximum Bending Moment
Z = Section Modulus

$M = \frac{wL^2}{8} = \frac{WL}{8}$, since $W = wL$

$M = \frac{4,289 \times 216}{8} = 115,803$ in. Kips

$S = \frac{M}{Z} = \frac{115,803,000 \text{ in\#}}{5,503 \text{ in}^3} = 21,044 \text{ \#/in}^2 < 41,600 \text{\#/in}^2$

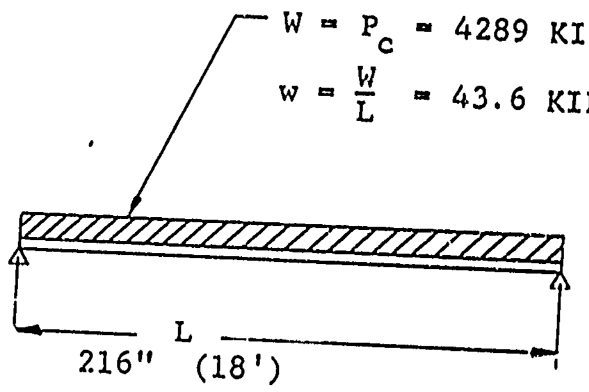
$\therefore$ Column section is satisfactory for bending stresses. Concrete filling of column will prevent buckling or twisting of column.

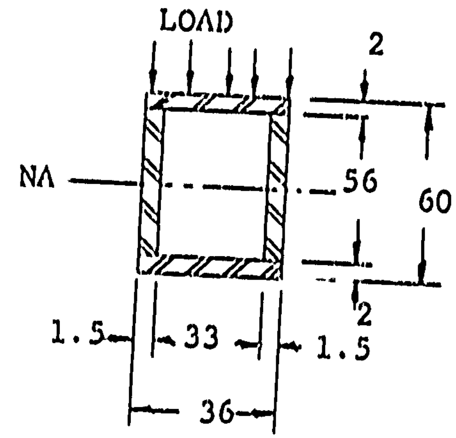
$$I_{na} = \frac{36 \times 60^3}{12} - \frac{33 \times 56^3}{12} = (3 \times 60^3) - (2.75 \times 56^3) = 165,078 \text{ in}^4$$

$$Z \text{ - Section Modulus} = \frac{I_{na}}{c} = \frac{165,078 \text{ in}^4}{30 \text{ in.}} = 5,503 \text{ in}^3$$

$W = P_c = 4289$ KIPS

$w = \frac{W}{L} = 43.6$ KIPS/IN





BLAST COLUMN DESIGN

B. COLUMN FRONT PLATE LOADING

Assume 1" wide strip and 45° stress distribution to concrete.

1. W = Column load per inch = $\dfrac{4{,}289 \text{ KIPS}}{216 \text{ in}}$ = 19,856#

2. R_c = Resistance of concrete = $S_c \times A$

   S_c = 3,900 PSI

   R_c = 3,900 × 1 × 9 = 42,900 #

3. Thus steel must resist a load of $(W - R_c)$ and $(\text{in} - R_c)$ can be used as the applied load.

   $W - R_c$ = 19,856 - 35,100

   W_A = Since concrete resistance is enough, any steel plate is O.K.

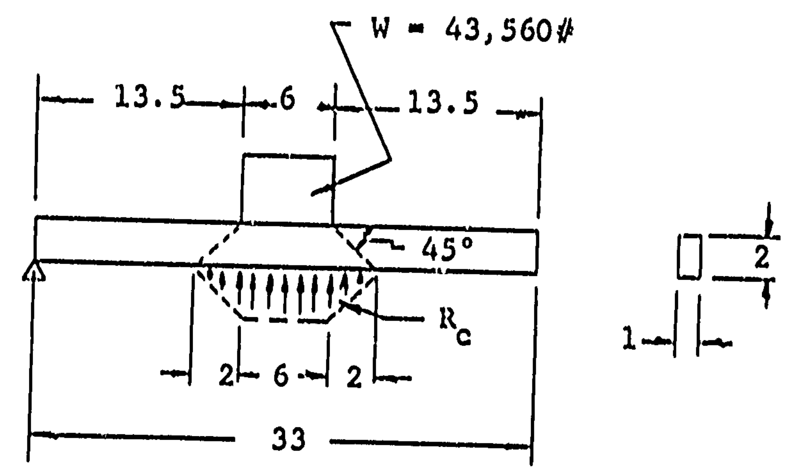
4. $S_s = \dfrac{M}{Z}$ $Z = \dfrac{bh^2}{6} = \dfrac{1 \times 3^2}{6} = 1.5$

   $M_{max} = \left[(18 \dfrac{W_a}{2})\right] + \dfrac{4\, W_a}{2 \times 2}$

   $M = 9\, W_a + W_a = 10\, W_a = 10 \times 660 = 6{,}600$ in#

   $S_s = \dfrac{6600 \text{ in\#}}{1.5 \text{ in}^3} = 4{,}400 \text{ \#/in}^2 < 41{,}600 \text{ \#/in}^2$

   ∴ 2" plate is O.K.



BLAST COLUMN DESIGN

C. CONCRETE BEARING STRESS

Assume column set 24" in concrete

$S_c = \frac{P}{A}$ P = Bearing Load = $\frac{P_c}{2}$

A = Bearing Area - W × h where W = column width

h = depth of column in concrete'

$$S_C = \frac{P_c}{2A} = \frac{4,289 \text{ KIPS}}{2 \times 36 \times 24} = 2,482 \text{ KIPS/in}^2 < 3,900\#/\text{in}^2$$

$\therefore$ Column set 24" in concrete in O.K.

REBOUND COLUMN DESIGN

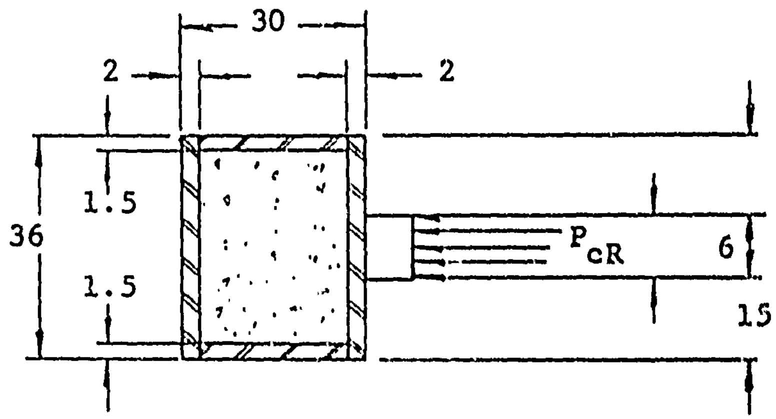
PLAN SECTION OF COLUMN

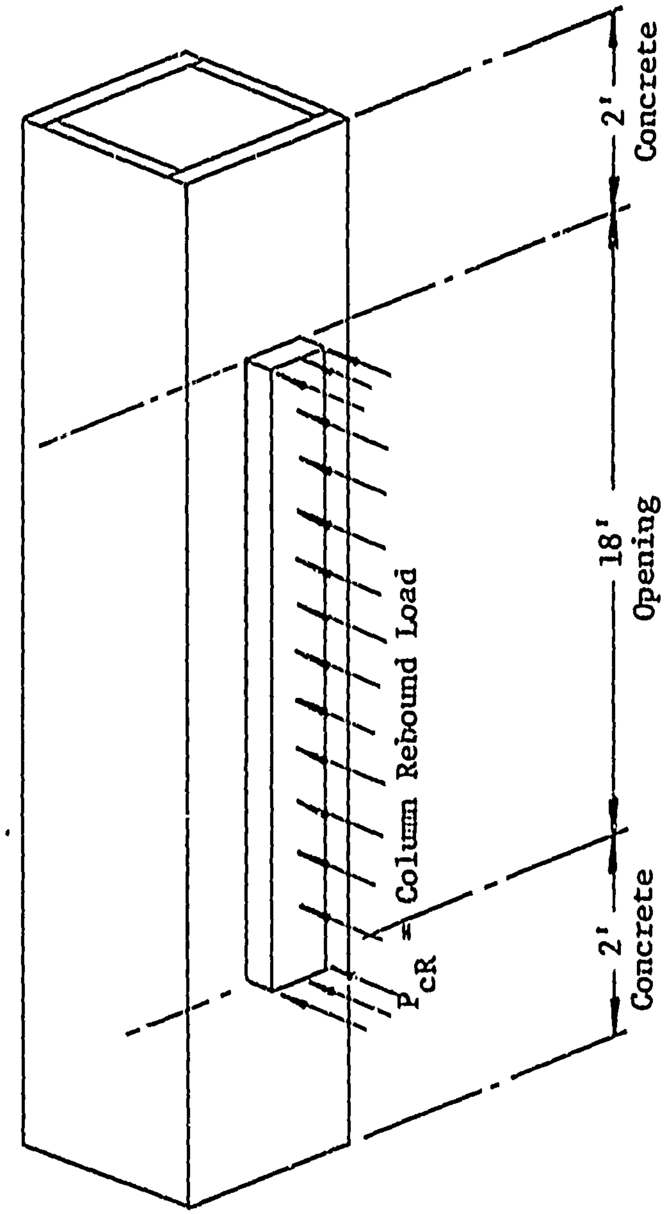
P_c = Column Load (applied blast)

P_{c_r} = Column Rebound Load

Assume 25% rebound

Then $P_{c_r} = \frac{P_c}{4} = \frac{4,289}{4}$ KIPS = 1,072 KIPS





REBOUND COLUMN DESIGN

A. COLUMN LOADING - NO ALLOWANCE FOR CONCRETE

$S = \frac{M}{Z}$ M = Maximum Bending Moment
Z = Section Modulus

$M = \frac{wL^2}{8} = \frac{WL}{8}$, since W = wL

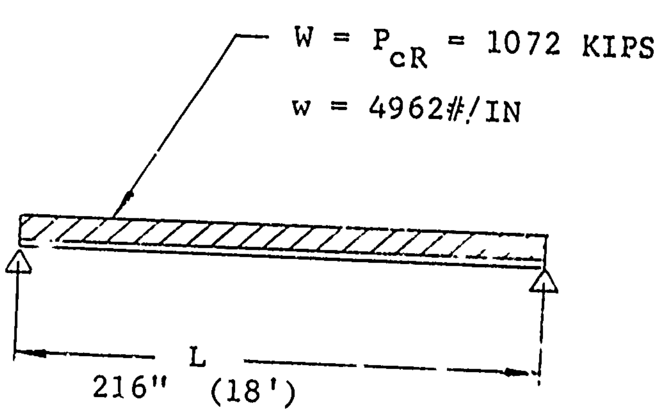
$M = \frac{1,072 \times 216}{8} = 28,944$ in. Kips

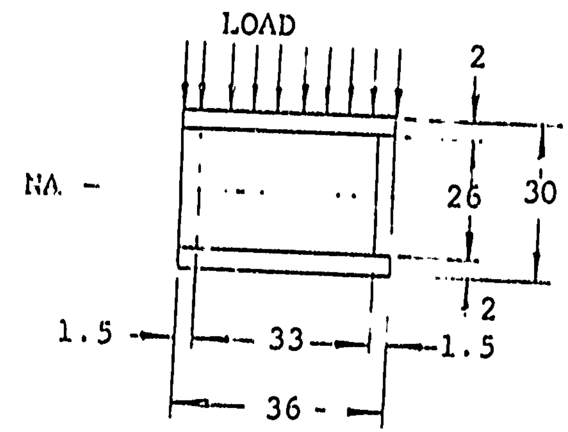
$S = \frac{M}{Z} = \frac{28,944,000 \text{ in\#}}{2,178} = 13,289\#/\text{in}^2 < 41,600\#/\text{in}^2$

∴ Column section is satisfactory for bending stresses. Concrete filling will prevent buckling or twisting of column.

$I_{na} = \frac{36 \times 30^3}{12} - \frac{33 \times 26^3}{12} = (3 \times 30^3) - (2.75 \times 26^3) = 32,660 \text{ in}^4$

$Z = \text{Section Modulus} = \frac{I_{na}}{c} = \frac{32,660 \text{ in}^4}{15 \text{ in}} = 2,178 \text{ in}^3$





REBOUND COLUMN DESIGN

B. <u>CHECK REBOUND COLUMN LOADED BY DIRECT BLAST ON COLUMN FACE - NO ALLOWANCE FOR CONCRETE</u>

1. $W_L = h \times W \times 144 \times 2P_r = 18 \times 3 \times 144 \times 394 = 3{,}064$ KIPS

2. $M = \dfrac{W_L L}{8} = \dfrac{3{,}064 \times 216}{8} = 82{,}728$ in-Kips

3. $S = \dfrac{M}{Z}$ $\qquad Z = 2{,}178 \text{ in}^3$

$S = \dfrac{82{,}728{,}000 \text{ in}^{\#}}{2{,}178 \text{ in}^3} = 37{,}983\#/\text{in}^2 \qquad 41{,}600\#/\text{in}^2$

Since no allowance was made for concrete, the concrete fill will make this column strong enough to withstand a direct blast.

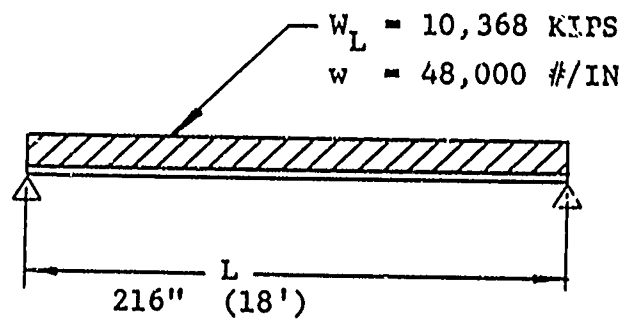
4. Concrete Bearing Stress
Column set 36" into concrete

$S_c = \dfrac{P}{A} \qquad P = \dfrac{W_L}{2} \qquad A = (48)(36)$

$S_c = \dfrac{3064}{(2)(36)(15)} = 3 \text{ KIPS/IN}^2$

$S_c = 2837 \ \#/\text{IN}^2 \qquad 3900 \ \#/\text{IN}^2$

$\therefore$ Column set 24" in concrete is O.K.



CALCULATIONS

2-WAY SPAN DOOR
SOLID DESIGN
SIMPLY SUPPORTED 4 SIDES
2'-6" x 4'-0", 100 PSI

TRIAL NO. 1

ELASTO-PLASTIC
DOOR NO. 60-12-26
CALCULATIONS BY T.A.
CHECKED BY H.S.

GIVEN:

t	= Assumed Thickness	=	2.50 Inches
T	= Load Duration	=	.050 Sec.
P_r	= Peak Reflected Pressure	=	500 PSI
W	= Total Weight of Door	=	1021 Lbs.
a	= Short Span of Door	=	30 Inches
b	= Long Span of Door	=	48 Inches
β	= Timoshenko Moment Constant	=	.0862
α	= Timoshenko Deflection Constant	=	.0906
K_{LM}	= Mass-Load Constant	=	.74 ELASTIC; .58 PLASTIC

Figure IV-4

FIND:

1. ELASTIC RESISTANCE (KIP)

$$R_{el} = \frac{6.933 \times t^2 \times b}{\beta \times a} = \frac{6.933 \times 2.50^2 \times 48}{.0862 \times 30}$$

$$= \frac{2079.90}{2.586} = \underline{804}$$

2. ELASTIC DEFLECTION(FEET)

$$X_{el} = \frac{6.933 \times \alpha \times a^2}{360 \times 10^3 \times t \times \beta} = \frac{.0906 \times 30^2 \times 6.933}{360 \times 10^3 \times 2.5 \times .0862}$$

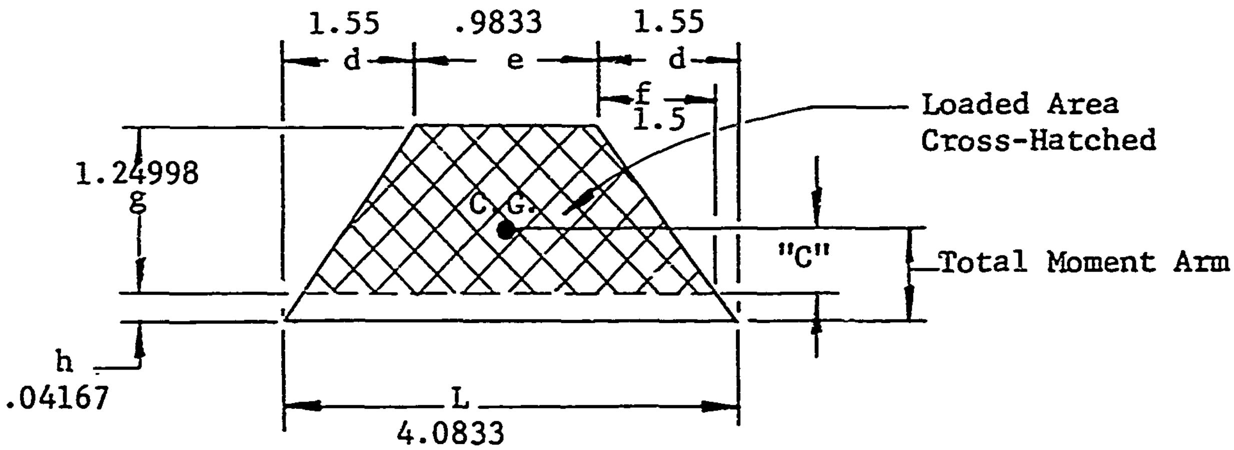
$$= \frac{565.31682}{77,580} = .007287$$

3. PLASTIC MOMENT (KIP-Inch/Inch)

$$M_p = 10.4 \times t^2 = 10.4 \times 2.5^2 = 65$$

4. ASSUMED TRAPEZOID FOR CRACK-LINE SECTION

(All dimensions in feet)



5. AREA OF TRAPEZOID LOADED (SQUARE FEET)

$$A = (f + e) \times g = (1.5 + .9833) \times 1.24998 = 3.10408$$

6. MOMENT ARM "c" (FEET)

$$"c" = \frac{\frac{f \times g^2}{3} + \frac{e \times g^2}{2}}{A}$$

$$= \frac{\frac{1.5 \times 1.24998^2}{3} + \frac{.9833 \times 1.24998^2}{2}}{3.10408}$$

$$= .49915$$

7. TOTAL MOMENT ARM (FEET)

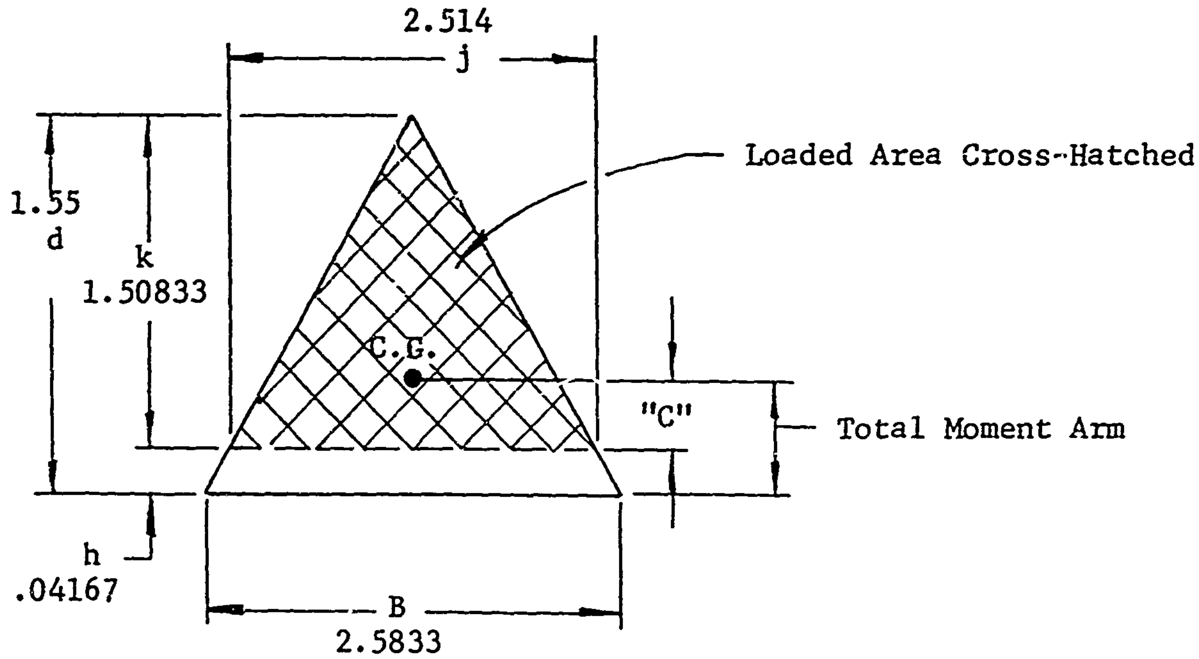
$$TMA = "c" + h = .4991511 + .04167 = .54082$$

8. UNIT RESISTANCE (Kip/Foot^2)

$$R_{unit} = \frac{M_p \times L}{TMA \times A} = \frac{65 \times 4.0833}{.54082 \times 3.10408} = 158$$

9. ASSUMED TRIANGLE FOR CRACK-LINE SECTION

(All dimensions in feet)



10. AREA OF TRIANGLE LOADED (SQUARE FEET)

$$A = 1/2 \times k \times j = 1/2 \times 1.50833 \times 2.514 = 1.8960$$

11. MOMENT ARM "c" (FEET)

$$"c" = \frac{k}{3} = \frac{1.50833}{3} = .50278$$

12. TOTAL MOMENT ARM (FEET)

$$TMA = "c" + h = .50278 + .04167 = .54445$$

13. UNIT RESISTANCE (Kip/Foot^2)

$$R_{unit} = \frac{M_p \times F}{TMA \times A} = \frac{65 \times 2.5833}{.54445 \times 1.8960}$$

$$= \frac{167.9145}{1.032277} = 163$$

14. TOTAL EFFECTIVE RESISTANCE (KIP)

$$R_1 = 2 \times (R_{\underset{\triangle}{unit}} \times A + R_{\underset{\triangle}{unit}} \times A) \times .80$$

$$= 2 \times (158 \times 3.10408) + (163 \times 1.8960) \times .80$$

$$= 1.60 \times 799.49 = 1279$$

15. PEAK LOAD (KIP)

$$P_o = \frac{P_r \times a \times b}{1{,}000} = \frac{500 \times 30 \times 48}{1{,}000} = 720$$

16. ELASTIC SPRING CONSTANT (Kip/Foot)

$$K_1 = \frac{R_{el}}{X_{el}} = \frac{804}{.007287} = .110333 \times 10^6$$

17. PLASTIC SPRING CONSTANT (Kip/Foot)

(Assume $X_1 = 3\ X_{el}$)

$$K_2 = \frac{R_1 - R_{el}}{X_1 - X_{el}} = \frac{1272 - 804}{.005757} = \frac{475}{.005757}$$

$$= .082508 \times 10^6$$

18. EFFECTIVE MASS (Kip - Sec^2/Foot)

$$M_e = \frac{W \times K_{LM}}{32,200} = \frac{1021 \times .74}{32,200} = .023464$$

$$M_p = \frac{W \times K_{LM}}{32,200} = \frac{1021 \times .58}{32,200} = .018391$$

19. NATURAL PERIOD (SECONDS)

$$T_n = 2\pi \times \sqrt{\frac{M_e}{K_1}}$$

$$= 6.2832 \times \sqrt{\frac{.023464}{.110333 \times 10^6}}$$

$$= 6.2832 \times \sqrt{.000000212665295}$$

$$= 6.2832 \times .0004612 = .002898$$

20. CONSTANTS FOR EXTRAPOLATION TABLE

ELASTIC

a. $\frac{T_n}{10} = \frac{.0029}{10} = .00029$ Sec.

b. $\triangle t = .0002$ Sec.

c. $(\triangle t)^2 = 4 \times 10^{-8}$ Sec.^{2}

d. $P_o = 720$Kip

e. $P_1 = P_o \left(1 - \frac{\triangle t}{.050}\right) = 720 \left(1 - \frac{.0002}{.050}\right)$

$= 717$ KIP

f. $P_o - P_1 = 720 - 717 = 3$ Kip

g. $a_o = \frac{1}{m_e} \times \left(\frac{P_o}{2} + \frac{P_1 - P_o}{6}\right)$

$= \frac{1}{.023464} \left(\frac{720}{2} - \frac{3}{6}\right) = 15{,}321$

h. $X_1 = a_o \times (\triangle t)^2 = 15{,}321 \times 4 \times 10^{-8}$

$= .000613$ ft.

i. $\frac{(\triangle t)^2}{m_e} = \frac{4 \times 10^{-8}}{.023464} = 170 \times 10^{-8}$

<u>ELASTO-PLASTIC</u> $M_e \cong M_{ep}$

* <u>PLASTIC</u> (For X_1 $3X_{el}$ only)

a. $\frac{(\Delta t)^2}{m_p}$ =

b. $\bar{K}_2$ =

c. R_{el} =

d. R_x = $R_{el} + K_2 (X_x - X_{el})$

* Not used this calculation

ACCELERATION IMPULSE EXTRAPOLATION TABLE

$X_{el} = .007287$ $R_{el} = 804$ $K_1 = 110,333$ $K_2 = 82,508$

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{m}$	$A_n(\Delta t)^2$ (Feet)	$2X_n$ (Feet)	$X_n - 1$ (Feet)	$X_n + 1$ (Feet)	Remarks
0	0	720	0	720	170×10^{-8}	.000613	0	0	0	
1	.0002	717	68	649	"	.001103	.001226	0	.000613	
2	.0004	714	257	457	"	.000777	.004568	.000613	.002329	
3	.0006	711	532	179	"	.000304	.009644	.002329	.004822	← ELASTIC
4	.0008	708	831	-123	"	-.000209	.015238	.004822	.007619	
5	.0010	705	1045	-340	"	-.000578	.020414	.007619	.010207	
6	.0012	702	1210	-508	"	-.000864	.024434	.010207	.012217	
7	.0014	699	1305	-606	"	-.001030	.026726	.012217	.013363	
8	.0016	696	1315	-619	"	-.001052	.026958	.013363	.013479	← MAX.
9	.0018	693	1212	-519	"	-.000882	.025086	.013479	.012543	
10	.0020	690	1011	-321	"	-.000546	.021450	.012543	.010725	
11	.0022	687	750	- 63	"	-.000107	.016722	.010725	.008361	
12	.0024	684	478	206	"	.000350	.011780	.008361	.005890	
13	.0026	681	244	437	"	.000743	.007538	.005890	.003769	
14	.0028	678	92	586	"	.000996	.004782	.003769	.002391	
15	.0030	675	49	626	"	.001064	.004018	.002391	.002009	← MIN.
16								.002009	.002691	
17										
18										
19										
20										
21										

RESULTS

Maximum Deflection = .013479
Elastic Deflection = .007287
Permanent Deflection = .006192

Ratio $= \frac{1315}{720} = 1.83$

Max. Rebound =

At .5" allowable total deflection - will take 6.7 max. blasts

R_x TABLE (T = .05)

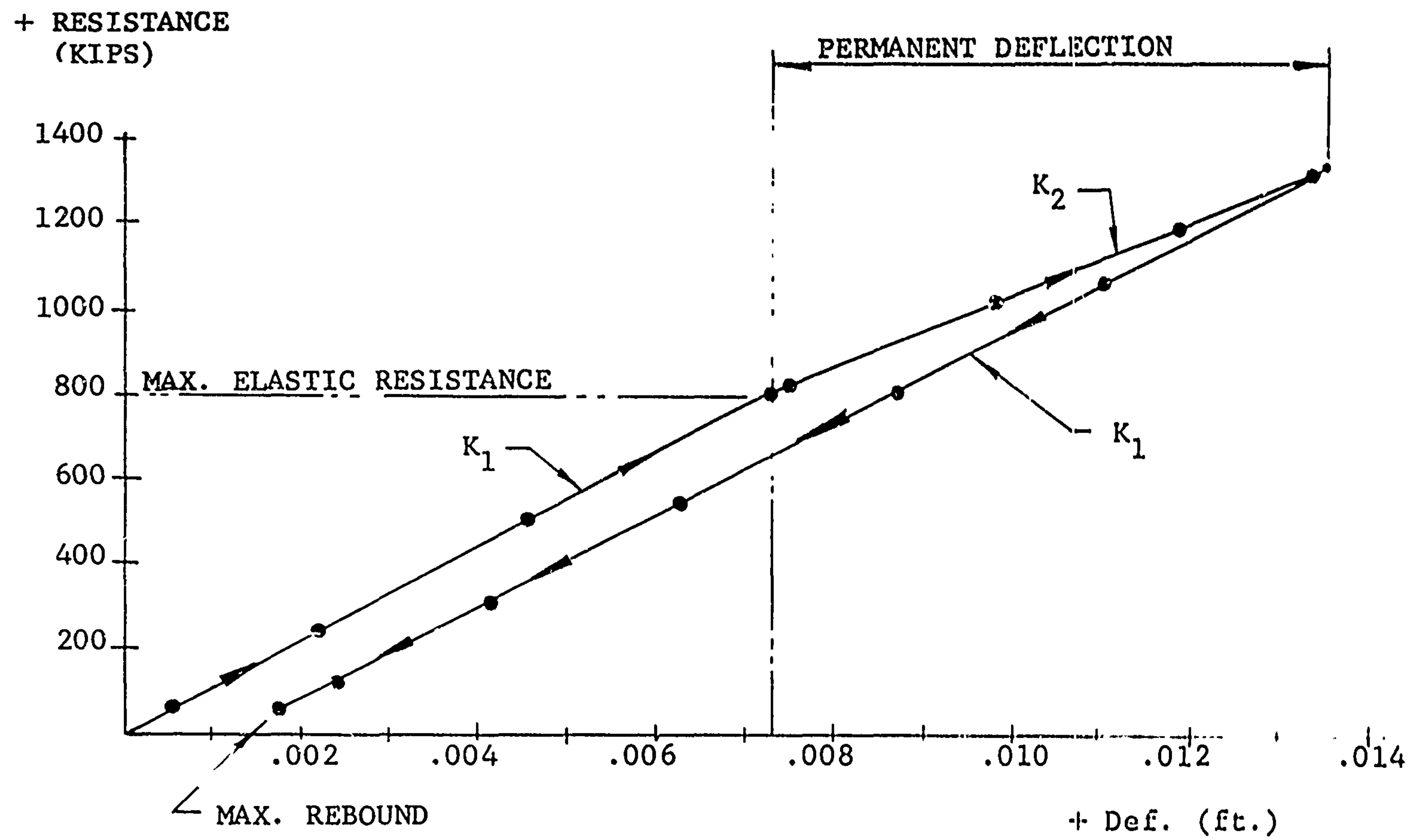
Plastic Range to Maximum R_x

X_x −	X_{el} =	×	K_2 =	+	R_{el} =	R_x
.007619	.007287	.000332	82,508	27	804	831
.010207	"	.002920	"	241	"	1045
.012217	"	.004930	"	406	"	1210
.013363	"	.006076	"	501	"	1305
.013479	"	.006192	"	511	"	1315

R_x TABLE

Maximum R_x to Minus R_{el}

$\bar{R}_{Max.}$ −	[($\bar{X}_{Max.}$	− $\bar{X}_x$)	÷ ×	$\bar{K}_1$ ÷	]	= $\bar{R}_x$
1315	.013479	.012543	.000936	110,333	103	1212
"	"	.010725	.002754	"	304	1011
"	"	.008361	.005118	"	565	750
"	"	.005890	.007589	"	837	478
"	"	.003769	.009710	"	1071	244
"	"	.002391	.011088	"	1223	92
"	"	.002009	.011470	"	1266	49



Scale:	Approved by:	
DOOR NO. 60-12-26 - T1 2-1/2" THICK SOLID STEEL - 100 PSI INCIDENT		
LOAD DURATION - .050 Sec.		

20. CONSTANTS FOR EXTRAPOLATION TABLE (T = .0041)

ELASTIC

a. $\frac{T_n}{10} = \frac{.0029}{10} = .00029$

b. $\Delta t = .0002$

c. $(\Delta t)^2 = 4 \times 10^{-8}$

d. $P_o = \frac{P_r \times A}{1{,}000} = 720$ KIP

e. $P_1 = P_o \left(1 - \frac{\Delta t}{.0041} \right) = 720 \left(1 - \frac{.0002}{.0041}\right) = 685$ KIP

f. $P_o - P_1 = 720 - 685 = 35$ KIP

g. $a_o = \frac{1}{m_e} \times \left(\frac{P_o}{2} + \frac{P_1 - P_o}{6} \right)$

$= \frac{1}{.023464} \left(\frac{720}{2} - \frac{35}{6} \right) = 15{,}094$

h. $X_1 = a_o \times (\Delta t)^2 = 15{,}094 \times 4 \times 10^{-8} = .000604$

i. $\frac{(\Delta t)^2}{m_e} = \frac{4 \times 10^{-8}}{.023464} = 170 \times 10^{-8}$

ELASTO-PLASTIC $\quad M_e \cong M_{ep}$

* PLASTIC

* Not used this calculation

ACCELERATION IMPULSE EXTRAPOLATION TABLE

$X_{e1} = .007287$ $R_{e1} = 804$ $K_1 = 110,333$ $K_2 = 82,508$

N	t (Sec.)	P_n (Kips)	R_n (Kips)	$P_n - R_n$ (Kips)	$\frac{(\Delta t)^2}{m}$	$A_n(\Delta t)^2$ (Feet)	$2X_n$ (Feet)	X_{n-1} (Feet)	X_{n+1} (Feet)	Remarks
0	0	720	0	720	170×10^{-6}	.000604	0	0	0	
1	.0002	685	67	618	"	.001051	.001208	0	.000604	
2	.0004	650	249	401	"	.000682	.004518	.000604	.002259	
3	.0006	615	507	108	"	.000182	.009192	.002259	.004596	
4	.0008	580	785	-205	"	-.000349	.014230	.004596	.007115	
5	.0010	545	971	-426	"	-.000724	.018570	.007115	.009285	
6	.0012	510	1088	-578	"	-.000983	.021462	.009285	.010731	
7	.0014	475	1126	-651	"	-.001107	.022388	.010731	.011194	← MAX.
8	.0016	440	1055	-615	"	-.001046	.021100	.011194	.010550	
9	.0018	405	868	-463	"	-.000787	.017720	.010550	.008860	
10	.0020	370	595	-225	"	-.000383	.012766	.008860	.006383	
11	.0022	335	280	55	"	.000094	.007046	.006383	.003523	
12	.0024	300	- 24	324	"	.000551	.001550	.003523	.000775	
13	.0026	265	-266	531	"	.000903	-.002844	.000775	-.001422	
14	.0028	230	-409	639	"	.001086	-.005432	-.001422	-.002716	
15	.0030	195	-432	627	"	.001066	-.005848	-.002716	-.002924	← REVERSE
16								-.002924	-.002066	
17										
18										
19										
20										
21										

Ratio $= \frac{432}{1315} = 32.9\%$

Max. Rebound = 432 Kips

R_x TABLE (T = .0041)

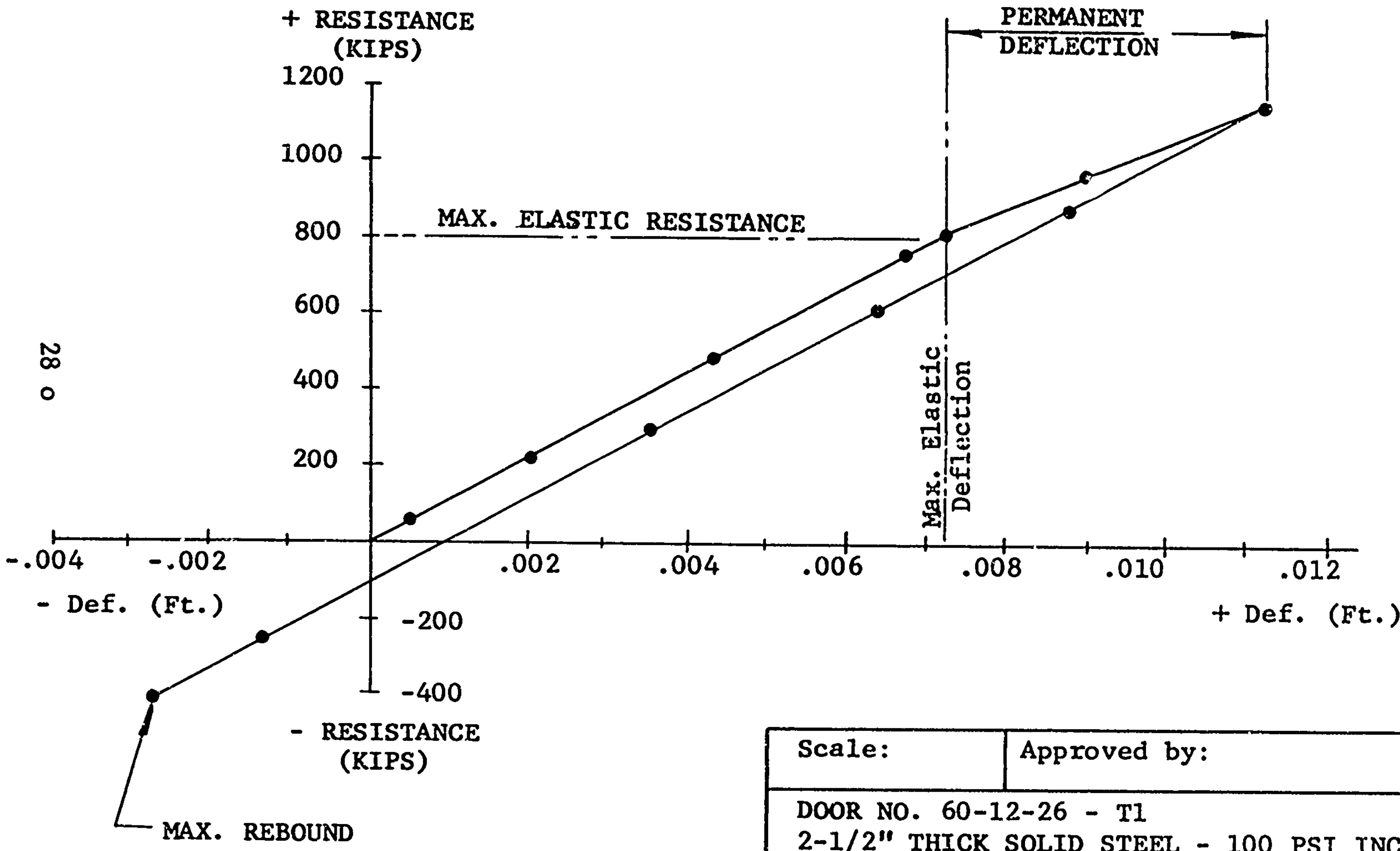
Plastic Range to Maximum R_x

X_x −	X_{el} =	×	K_2 =	+	R_{el} =	R_x
.009285	.007287	.001998	82,508	167	804	971
.010731	"	.003444	"	284	"	1088
.011194	"	.003907	"	322	"	1126

R_x TABLE

Maximum R_x to Minus R_{el}

$R_{Max.}$ −	[($X_{Max.}$	− X_x) =	×	K_1 =	]	= R_x
1126	.011194	.010550	.000644	110,333	71	1055
"	"	.008860	.002334	"	258	868
"	"	.006383	.004811	"	531	595
"	"	.003523	.007671	"	846	280
"	"	.000775	.010419	"	1150	- 24
"	"	-.001422	.012616	"	1392	-266
"	"	-.002716	.013910	"	1535	-409
"	"	-.002924	.014118	"	1558	-432



Scale:	Approved by:	
DOOR NO. 60-12-26 - T1 2-1/2" THICK SOLID STEEL - 100 PSI INCIDENT		
LOAD DURATION - .0041 Sec.		

BEARING STRESS

A =
B = 32
C = 50
D = 48
E = 18
F = 16
T = 1

R_M = Maximum Door Resistance = 1,315,000

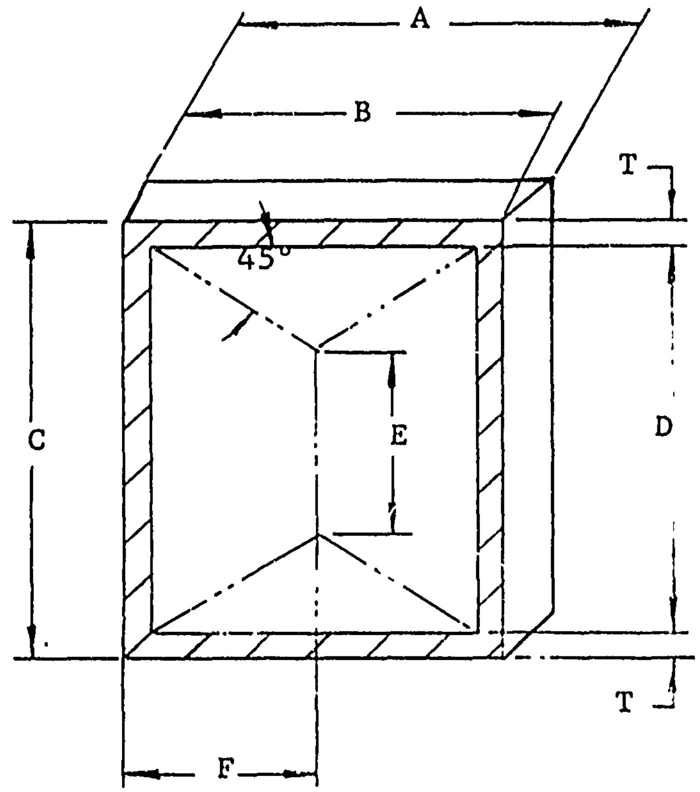
Bearing Stress (along long edge is a maximum) =

$$\frac{R_M \times \frac{(c + E)}{2} \times F}{B \times C \times D \times T}$$

$$= \frac{1,315,000 \times 34 \times 16}{32 \times 50 \times 48 \times 1} = \frac{44,710,000}{4,800}$$

S_B = 9,315 for T = 1"

Use T = 1/2" (S_B = 18,730#/D")



VERTICAL STRIKER THICKNESS CALCULATION

Take a typical 1" long vertical strip.

Average Force per Lineal Inch = $F = S_B \times T = 9{,}315$

Bending Moment = $M_b = F \times D = 9{,}315 \times .625 = 5{,}822$

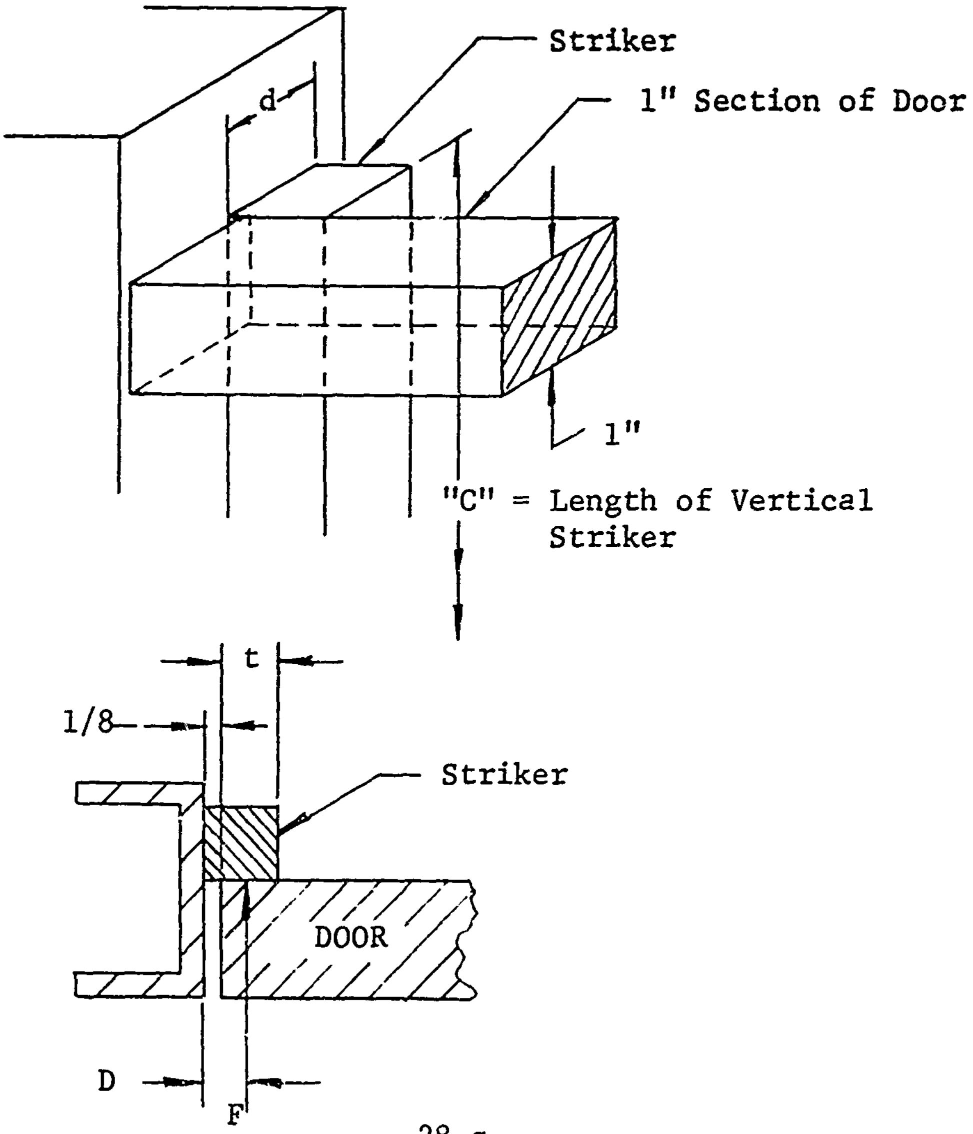
Minimum Required Thickness = $d = \sqrt{\frac{6\ M_b}{41{,}600}} = \sqrt{\frac{34{,}932}{41{,}600}}$

$= \sqrt{.839712} = .916$ (for T = 1")

Use d = 3/4" (.7117 Min.) (for T = 1/2")

F_c = Total force on vertical striker

41,600 = allowable bending stress



REBOUND LOAD CALCULATION FOR LOCK BOLTS

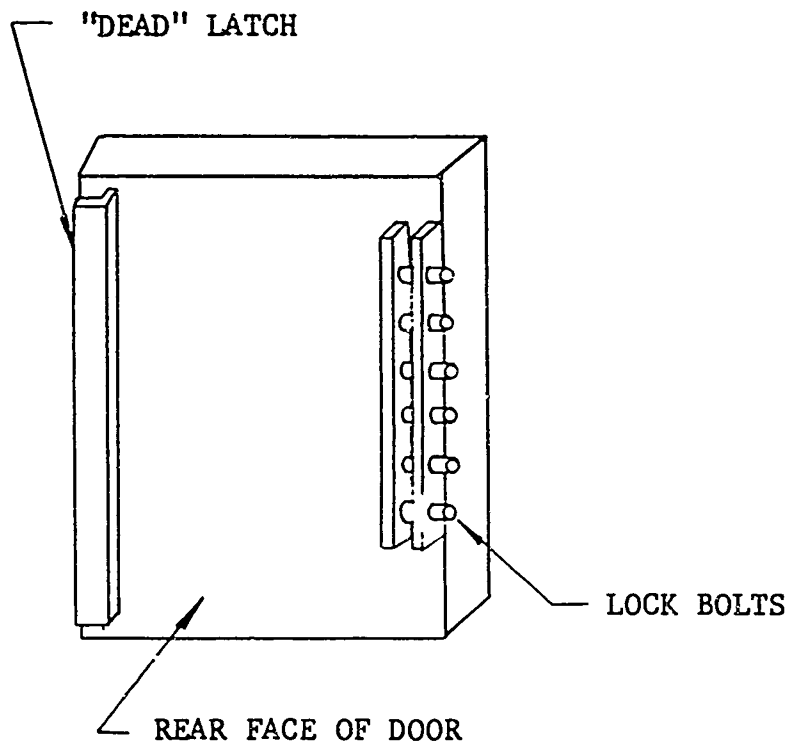
Consider rebound resisted equally by "dead latch" and lock bolts.

Then:

$$\text{Rebound force per bolt} = P = \frac{\text{Max. Rebound Force}}{2 \times \text{no, of lock bolts}}$$

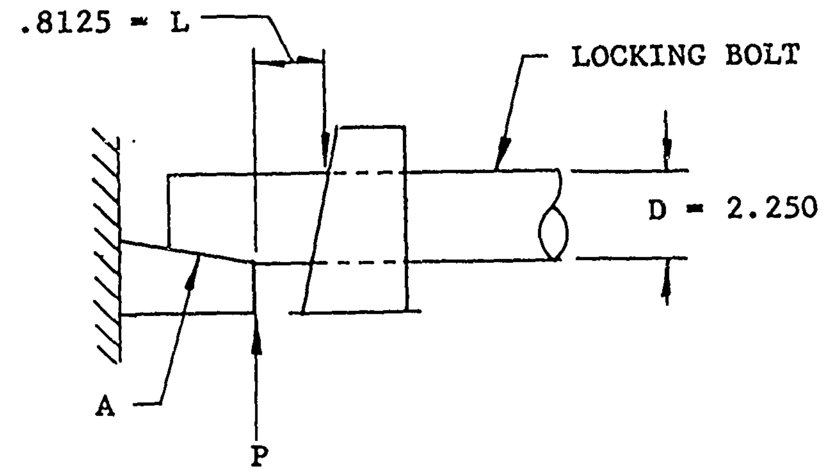
$$= \frac{432{,}000}{8} = 54{,}000$$

Maximum total rebound force is obtained from rebound calculations.



LOCK BOLT CALCULATIONS - REBOUND - BLAST DOOR

P = 54,000



P = Equivalent Static Force per Bolt in Pounds

L = Length in Inches

D = Diameter in Inches

A = Bearing Area in Sq. In.

Min. "A" = 1.800

1. Vertical Shear $= \dfrac{4P}{\pi D^2} = \dfrac{4 \times 54{,}000}{\pi \times 5.0625} = \dfrac{216{,}000}{15.904} = 13{,}582$

2. Horiz. Shear $= \dfrac{16P}{3 \times \pi \times D^2} = \dfrac{16 \times 54{,}000}{3 \times \pi \times 5.0625} = \dfrac{864{,}000}{47.712} = 18{,}109$

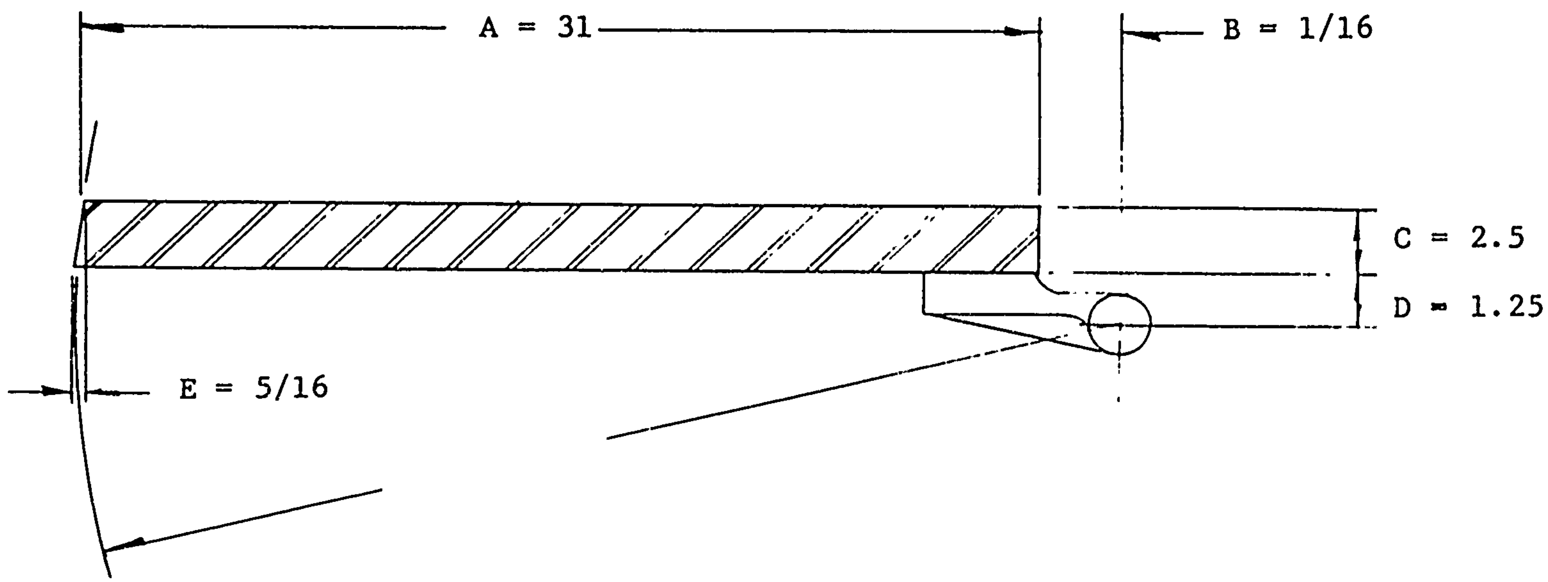
3. Bending Stress $= \dfrac{32P \times L}{\pi D^3} = \dfrac{32 \times 54{,}000 \times .8125}{3.1416 \times 11.3906} = \dfrac{1{,}404{,}000}{35.785} = 39{,}234$

4. Bearing Stress $= \dfrac{P}{A} = \dfrac{54{,}000}{2.336} = 23{,}116$

ALLOWABLE STRESSES - #A-7 STEEL:

1. 21,000 PSI
2. 21,000 PSI
3. 41,600 PSI
4. 30,000 PSI

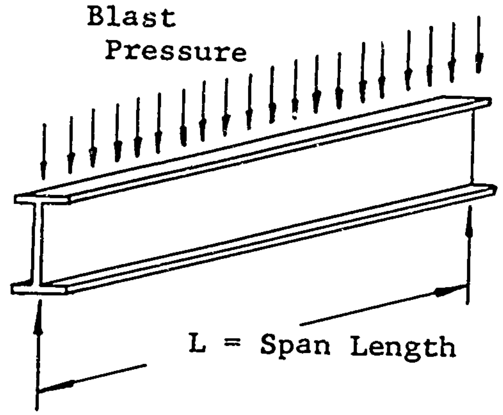
CALCULATIONS - DOOR SWING AND DOOR TAPER

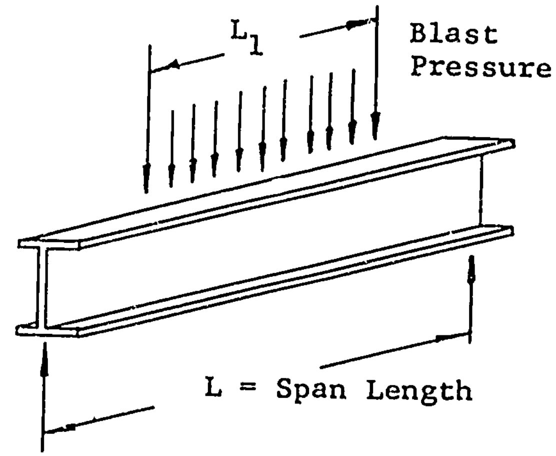


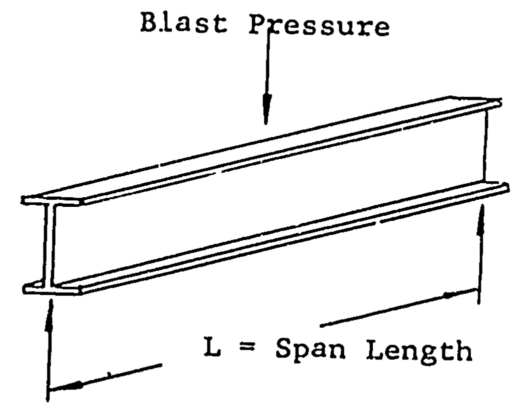
$$\text{Swing} = S = \sqrt{(A + B)^2 + (C + D)^2} = \sqrt{(31.0625)^2 + (3.75)^2} = \sqrt{978.94140625} = 31.2880$$

$$\text{Taper} = E = \frac{C^2 + CD}{(A + B)} = \frac{6.25 + 3.125}{31.0625} = \frac{9.375}{31.0625} = .30181 \qquad \text{Use } 5/16''$$

K_{LM} FACTOR FOR VARIOUS BEAM BLAST LOADING CONDITIONS







UNIFORM BLAST LOADING OVER ENTIRE SPAN

Strain Range	Load-Mass Factor K_{LM}
Elastic	.78
Plastic	.66

SYMMETRICAL UNIFORM BLAST LOADING OVER PART OF SPAN

Strain Range	Load-Mass Factor K_{LM} *
Elastic	$\frac{384 \times L^3}{\pi^4(8L^3+L_1^3-4LL_1^2)}$
Plastic	$\frac{2L}{3(2L - L_1)}$
Elasto-Plastic	$.5(K_{LM_e}+K_{LM_p})$

* Expressed in terms of L and L_1

CONCENTRATED BLAST LOAD AT MID-POINT

Strain Range	Load-Mass Factor K_{LM} A	B
Elastic	1.0	.49
Plastic	1.0	.33

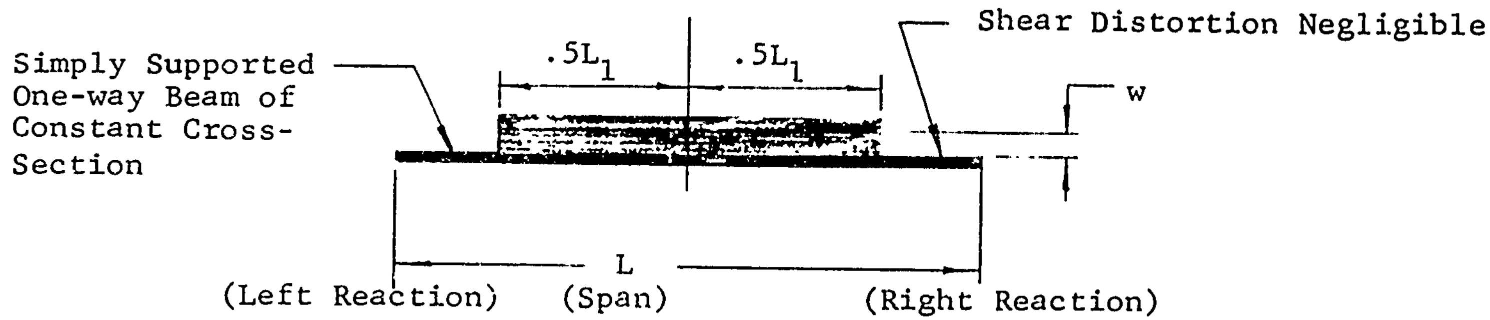
A = Concentrated Mass

B = Uniform Mass

Figure IV-5

DERIVATION OF K_{LM} FOR BEAM

PARTIALLY LOADED SPAN



GIVEN:

Simply supported one-way beam of constant cross-section

FIND:

K_{LM} - Elastic and Plastic

$$\text{Total Load} = w \times L_1 = W$$

$$\text{Spring Constant} = k = \frac{384 \times E \times I}{(8L^3 + L_1^3 - 4LL_1^2)}$$

ELASTIC

$$2\pi \times \sqrt{\frac{m_e}{k}} = \frac{2}{\pi \times n^2} \times \sqrt{\frac{m \times L^3}{E \times I}}$$

(Consider fundamental node only $n = 1$)

$$\frac{\pi^2 \times m_e}{k} = \frac{m \times L^3}{\pi^2 \times E \times I}$$

$$K_{LM_e} = \frac{m_e}{m} = \frac{k \times L^3}{\pi^4 \times E \times I} = \frac{384 \times E \times I \times L^3}{\pi^4 \times E \times I \times (8L^3 + L_1^{\ 3} - 4LL_1^{\ 2})}$$

$$= \frac{384\ L^3}{\pi^4\ (8L^3 + L_1^{\ 3} - 4LL_1^{\ 2})}$$

PLASTIC

$$\frac{W}{2} \times L_o - M_{\mathbb{C}} = \frac{I_{AB}\ \ddot{X}_G}{\frac{L}{2}} \qquad \left(\text{Where } L_o = \frac{L}{2} - \frac{L_1}{4} = \frac{2L - L_1}{4}\right)$$

$$W - 2\ M_{\mathbb{C}} = \frac{4\ I_{AB} \times \ddot{X}_{CL}}{L \times L_o} = m_e\ \ddot{X}_{CL}$$

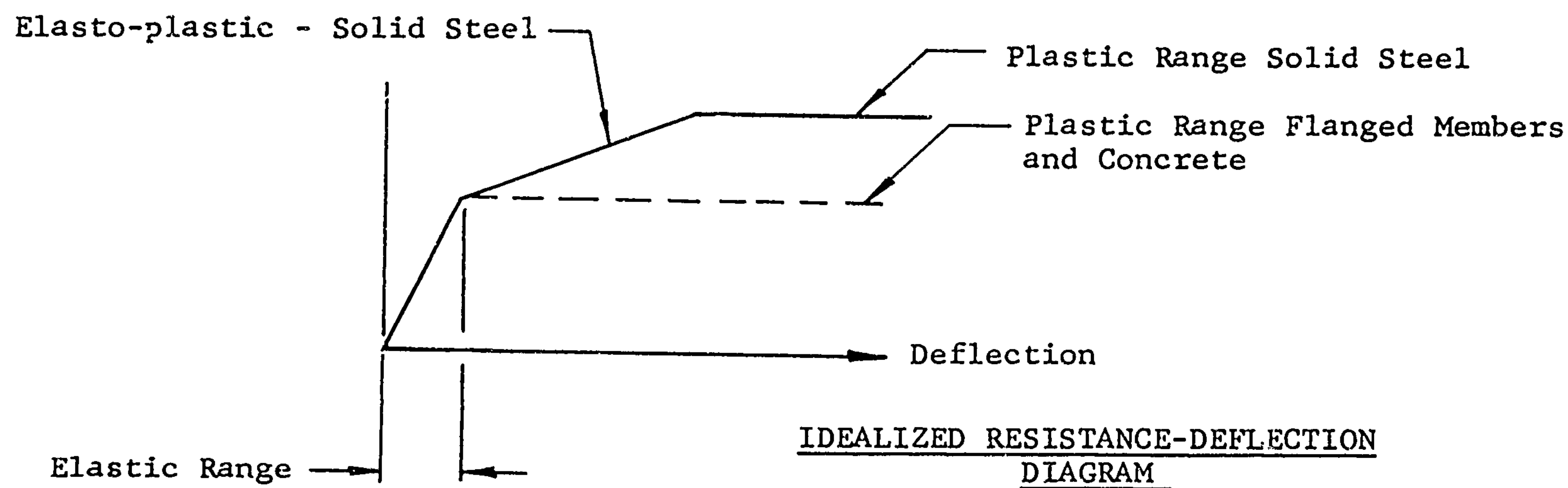
$$m_e = \frac{4\ I_{AB}}{L \times L_o} = \frac{4}{L \times L_o} \times \frac{m\ L^2}{24_6}$$

$$K_{LM_p} = \frac{m_e}{m} = \frac{m \times L}{m \times 6 \times L_o} = \frac{L}{6L_o} = \frac{4 \times L}{6(2L - L_1)} = \frac{2 \times L}{3(2L - L_1)}$$

ELASTO-PLASTIC

$$K_{LM_{ep}} \approx .05\ (K_{LM_e} + K_{LM_p})$$

DERIVATION OF K_{LM} FOR BEAM - PARTLY LOADED SPAN



IDEALIZED RESISTANCE-DEFLECTION DIAGRAM

MAXIMUM POSSIBLE ERRORS USING FIRST MODE ONLY - ELASTIC RANGE

UNIFORM LOAD ($\frac{T}{T_n} \longrightarrow > 2$)			CONCENTRATED LOAD ($\frac{1}{T_n} \longrightarrow > 2$	
Absolute*	Average**		Absolute*	Average**
$< 14\%$	$< 2\%$	Support Shear	$< 70\%$	
$< 5\%$		Mid-Span Moment	~ 0	$< -10\%$
$< 1\%$		Mid-Span Deflection	~ 0	

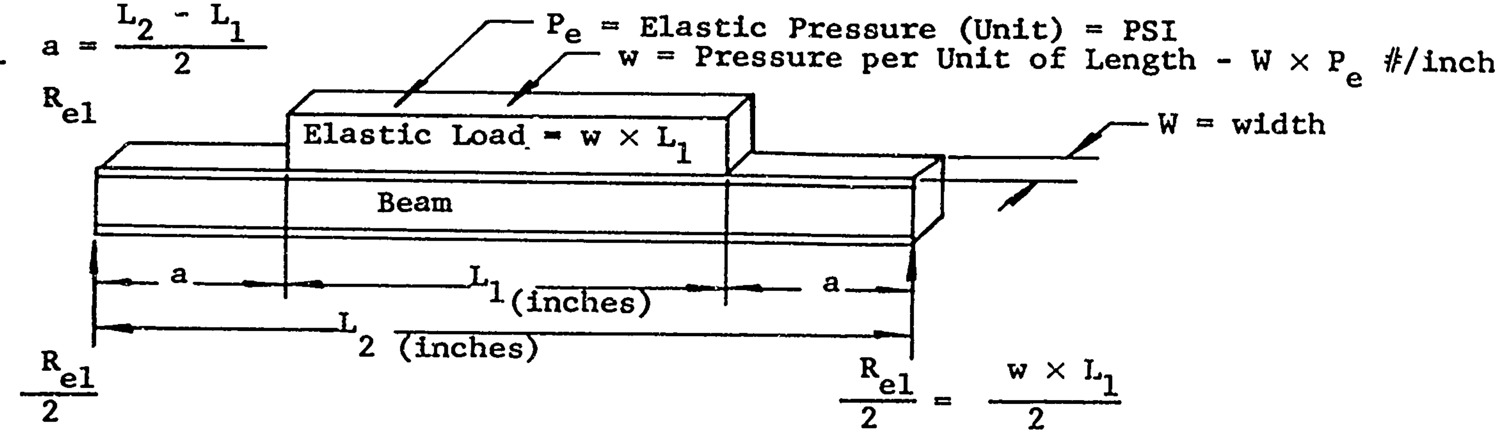
* Assuming Maximums of all Modes Occur Simultaneously and Neglecting Damping

** Using Average of all Modes and Neglecting Damping

DERIVATION OF R_{el}, X_{el}, and K_1 FOR PARTIALLY LOADED SPAN

GIVEN: $a = \dfrac{L_2 - L_1}{2}$

FIND: R_{el}



$$R_{el} = w \times L_1 = \frac{w \times 8M}{w\,(2L_2 - L_1)} = \frac{8M}{(2L_2 - L_1)} = \frac{8 \times 41.6 \times S}{(2L_2 - L_1)} = \frac{332.8\ S}{(2L_2 - L_1)} \quad \text{K-\#}$$

or, if L_1 and L_2 are in feet:

$$R_{el} = \frac{332.8\ S}{12(2L_2 - L_1)} = \frac{27.73333\ S}{(2L_2 - L_1)} \quad \text{K-\#}$$

$$M_{elastic} = M_{max.\ @\ center} = \left[\frac{w \times L_1}{2} \times \frac{L_2}{2} - \frac{w \times L_1}{2} \times \frac{L_1}{4}\right] = \frac{w \times L_1 \times L_2}{4} - \frac{W \times L_1^{2}}{8}$$

$$= \frac{w \times w \times L_1 \times L_2}{8} - \frac{w \times L_1^{2}}{8} = \frac{wL_1}{8}(2L_2 - L_1) \text{ or } L_1 = \frac{8M}{w(2L_2 - L_1)}$$

Figure IV-6

GIVEN: w = Elastic load per lineal inch

FIND: X_{el} @ $x = \frac{L_2}{2}$

$$X_{el} = 2\int_a^{\frac{L_2}{2}} \frac{wxdx}{48\ EI}(3L_2^2 - 4x^2 \qquad \left[\begin{array}{l}\text{(Timoshenko "Strength of Materials"}\\ \text{2nd Edition, Part 1, Page 158)}\end{array}\right]$$

$$= \frac{2w}{48\ EI}\left[3L_2^2\int_a^{\frac{L_2}{2}} xdx - 4\int_a^{\frac{L_2}{2}} x^3dx\right] = \frac{2w}{48EI}\left\{3L_2^2\left[\frac{x^2}{2}\right]_a^{\frac{L_2}{2}} - 4\left[\frac{x^4}{4}\right]_a^{\frac{L_2}{2}}\right\}$$

$$= \frac{2w}{48EI}\left\{3L_2^2\left(\frac{L_2^2}{8} - \frac{a^2}{2}\right) - 4\left(\frac{L_2^4}{64} - \frac{a^4}{4}\right)\right\}$$

$$= \frac{w}{24\ EI}\left(\frac{3\ L_2^4}{8} - \frac{3\ a^2L_2^2}{2} - \frac{4\ L_2^4}{64} + \frac{4\ a^4}{4}\right)$$

$$= \frac{w}{24EI}\left(\frac{5}{16}L_2^4 - \frac{3\ a^2L_2^2}{2} + a^4\right)$$

But: $a = \frac{L_2 - L_1}{2}$

$$\therefore\ X_{el} = \frac{w}{24EI}\left[\frac{5}{16}L_2^4 - \frac{3}{2}L_2^2\left(\frac{L_2 - L_1}{2}\right)^2 + \left(\frac{L_2 - L_1}{2}\right)^4\right]$$

$$X_{el} = \frac{w}{24EI}\left[\frac{5}{16}L_2^4 - \frac{3}{2}L_2^2\left(\frac{L_2^2 - 2L_1L_2 + L_1^2}{4}\right) + \frac{L_2^4 - 4L_1L_2^3 + 6L_1^2L_2^2 - 4L_1^3L_2 + L_1^4}{16}\right]$$

$$= \frac{w}{24EI}\left[\frac{5}{16}L_2^4 - \frac{3}{8}(L_2^4 - 2L_1L_2^3 + L_1^2L_2^2) + \frac{L_2^4}{16} - \frac{1}{4}L_1L_2^3 + \frac{3}{8}L_1^2L_2^2 - \frac{1}{4}L_1^3L_2 + \frac{L_1^4}{16}\right]$$

$$= \frac{w}{24EI}\left(\frac{5}{16}L_2^4 - \frac{3}{8}L_2^4 + \frac{3}{4}L_1L_2^3 - \frac{3}{8}L_1^2L_2^2 + \frac{L_2^4}{16} - \frac{1}{4}L_1L_2^3 + \frac{3}{8}L_1^2L_2^2 - \frac{1}{4}L_1^3L_2 + \frac{L_1^4}{16}\right)$$

$$= \frac{w}{24EI}\left(\frac{1}{2}L_1L_2^3 - \frac{1}{4}L_1^3L_2 + \frac{L_1^4}{16}\right)$$

But: $w = \dfrac{332.8 \times S}{L_1(2L_2 - L_1)}$ - K #/Lineal Inch (per page 30 c)

$$\therefore \quad X_{el} = \frac{332.8 \times S}{L_1(2L_2 - L_1)} \times \frac{L_1}{24EI}\left(\frac{L_2^3}{2} - \frac{L_1^2L_2}{4} + \frac{L_1^3}{16}\right) \text{ Kip Inches}$$

$$= \frac{.46222 \times 10^{-6}}{(2L_2 - L_1)} \times \frac{S}{I}\left(\frac{8L_2^3 - 4L_1^2L_2 + L_1^3}{16}\right) \quad \text{" \quad "}$$

$$= 28.8888 \times 10^{-6} \times \frac{S}{I}\left(\frac{8L_2^3 - 4L_1^2L_2 + L_1^3}{2L_2 - L_1}\right) = .00002888 \times \frac{S}{I}\left(\frac{8L_2^3 - 4L_1^2L_2 + L_1^3}{2L_2 - L_1}\right)$$

or, if L_1 and L_2 are in feet:

$$X_{el} = .000346666 \times \frac{S}{I}\left(\frac{8L_2^3 - 4L_1^2L_2 + L_1^3}{2L_2 - L_1}\right)$$

Check this formula for case where $L_2 = L_1 = L$: $X_{el} = \dfrac{w}{24EI}\left(\dfrac{L^4}{2} - \dfrac{L^4}{4} + \dfrac{L^4}{16}\right)$

$$= \frac{w}{24EI}\left(\frac{5}{16}L^4\right) = \frac{5\ wL^4}{384\ EI} \quad \text{- Formula checks}$$

$$\text{Elastic Moment} = 41{,}600 \times S \ \text{"\#} = M_{el} \tag{1}$$

$$\text{Also, Elastic Moment} = \frac{w\,L_1}{8}(2L_2 - L_1) = M_{el} \tag{2}$$

$$\text{or } w = W \times P_e = \frac{8\,M_{el}}{L_1(2L_2 - L_1)} \tag{2a}$$

$$= \frac{8 \times 41{,}600 \times S}{L_1(2L_2 - L_1)} \quad \text{\#/lineal inch} \tag{2b}$$

$$= \frac{332.8 \times S}{L_1(2L_2 - L_1)} \quad \text{K \#/lineal inch} \tag{3}$$

Figure IV-7

FIND: K_1

$$K_1 = \frac{R_{e1}}{X_{e1}} = \frac{27.33333 \times S}{(2L_2 - L_1)} \times \frac{I\ (2L_1 - L_1)}{.000346666 \times S \times (8L_2^3 - 4L_1^2L_2 + L_1^3)}$$

$$= \frac{27.33333 \times I}{.000346666 \times (8L_2^3 - 4L_1^2L_2 + L_1^3)}$$

$$= 80{,}000 \times \frac{I}{8L_2^3 - 4L_1^2L_2 + L_1^3)}$$

Check this formula for case where $L_2 = L_1 = L$ (in feet)

$$K_1 = 80{,}000 \times \frac{I}{8L^3 - 4L^3 + L^3}$$

$$= 80{,}000 \times \frac{I}{5L^3} = 16{,}000 \times \frac{I}{L^3}$$ Formula checks.

DERIVATION OF CONSTANTS X_{el}, R_{el}, and K_1

w = Pressure

b is in inches
L is in feet
b = 12 L

$$\text{Stress} = \frac{M}{S}$$

or Moment = Stress × Section Modulus = 41,600 S Inch-lbs.

$$\text{Also, Moment} = \frac{w \times b^2}{8} = \frac{R \times b}{8} \qquad (R - w \times b = \text{Resistance})$$

$$\text{or } R = w \times b = \frac{8 \times M}{b} = \frac{8 \times 41,600 \times S}{b}$$

$$\therefore \underset{\text{(Inches)}}{X_{el}} = \frac{5 \times w \times b^4}{384\ EI} = \frac{(w\ b)(5\ b^3)}{384\ EI} = \frac{w\ b}{\frac{384\ EI}{5\ L^3}} = \frac{R}{K_1}\ \frac{(\text{lbs.})}{(\text{lbs/in})}$$

$$= \frac{8 \times 41,600 \times S \times 5 \times b^3}{b \times 384 \times E \times I} = \frac{8 \times 41,600 \times 5 \times b^2 \times S}{384 \times 30 \times 10^6 \times I}$$

$$= \frac{1,664,000 \times b^2 \times S}{11,520,000,000\ \ I} = .0001444\ \frac{b^2 \times S}{I} \quad \text{Inches}$$

$$\text{Or } \underset{\text{(Feet)}}{X_{el}} = \frac{.0001444\ (12L)^2 \times S}{12 \times I} = .0001444 \times 12 \times \frac{L^2 \times S}{I}$$

$$= .0017333 \times \frac{L^2 \times S}{I} \quad \text{Feet}$$

$t_y = \text{Stress}_{el} = \frac{M}{S}$ $\quad R_{el} = w_{el} \times L \quad w_{el} L^2 = R_{el} \times L$ (L is in feet)

$M = f_{dy} \times S = 41.6 \times S$ K-Ft.

$wb^2 = 8M$

$$R_{el} = \frac{8 \times M}{L} = \frac{8 \times 41.6 \times S}{L \times 12} = \frac{8 \times 41.6}{12} \left(\frac{S}{L}\right) = 27.7333\tfrac{1}{3} \left(\frac{S}{L}\right) \quad \text{K - \#}$$

$$K_1 = \frac{384 \times E \times I}{5 \times L^3} = \frac{384 \times 30 \times 10^6 \times I}{5 \times (12\ L)^3}$$

$$= \frac{384 \times 30 \times 10^6 \times I}{5 \times 12^3 \times L^3} = 1{,}333{,}333\tfrac{1}{3} \left(\frac{I}{L^3}\right) \quad \text{\#/In.}$$

$$= 1{,}333\tfrac{1}{3} \times \left(\frac{I}{L^3}\right) \quad \text{K/In.} \qquad \text{(Divided by 1,000)}$$

$$= 16{,}000 \left(\frac{I}{L^3}\right) \quad \text{K/Ft.} \qquad \text{(Divided by 12)}$$

$$\text{Also, } K_1 = \frac{R_{el}}{X_{el}} = \frac{27.7333 \times S}{L} \times \frac{I}{.0017333 \times L^2 \times S}$$

$$= \frac{27.7333}{.001733} \times \frac{I}{L^3} = 16{,}000 \left(\frac{I}{L^3}\right) \qquad \text{(Checks with above derivation)}$$

DERIVATION OF CONSTANTS R_{el} and X_{el}

Bending Moment - Section Modulus × Unit Stress

f_{dy} = Dynamic Yield Stress - 41.6 K for A-7 Steel

a = Short span in inches   b = long span in inches

q = Elastic unit pressure

β = Timoshenko constant

1. Elastic Moment (for 1" width) = $M_{el} = \frac{1 \times t^2}{6} \times f_{dy} = \frac{41.6}{6} t^2 = 6.933\ t^2$ - K in/lb.

Also, $M_{el} = \beta \times \quad \times a^2$ * or $= \frac{M_{el}}{\beta \times a^2} = \frac{6.933 \times t^2}{\beta \times a^2}$ - K Lb./sq. in.

$\therefore$ Total Elastic Resistance = $R_{el} = q \times$ Area

$$= \frac{6.933 \times t^2 \times b \times a}{\beta \times a^2} = \frac{6.933 \times t^2 \times b}{\beta \times a} \text{ - Kip}$$

* Timoshenko "Plates & Shells" p. 133

2. Elastic Deflection = $X_{el} = \dfrac{\alpha \times a^4 \times q}{E \times t^3}$ *

$q = \dfrac{6.933 \times t^2}{\beta \times a^2}$ - Kip Lb/sq. in.

α = Timoshenko Constant

β = Timoshenko Constant

t = thickness in inches

a = Short span of door in inches

b = Long span of door in inches

$$X_{el} = \frac{\alpha \times a^4 \times 6.933 \times t^2}{30 \times 10^6 \times t^3 \times \beta \times a^2} = \frac{\alpha \times a^2 \times 6.933}{30 \times 10^6 \times t \times \beta} \quad \text{Kip-Inches}$$

$$= \frac{6.933 \times \alpha \times a^2 \times 10^3}{30 \times 10^6 \times t \times \beta \times 12} \quad \text{Feet}$$

$$= \frac{6.933 \times \alpha \times a^2}{360 \times 10^3 \times t \times \beta} \quad \text{Feet}$$

* Timoshenko "Plates and Shells" p. 133

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